PRINTING INK

A HISTORY

With a Treatise on Modern Methods of Manufacture and Use

BY FRANK B. WIBORG

NEW YORK AND LONDON
HARPER & BROTHERS, PUBLISHERS

PRINTING INK

First Edition
C-A

LEVI ADDISON AULT

to whom

THIS WORK IS AFFECTIONATELY DEDICATED

Co-founder (with the author) of AULT & WIBORG, *in the year 1878, and at this time President of* THE AULT & WIBORG COMPANY, *of* "Hic et Ubique."

A present-day eminent authority on the manufacture of every description of PRINTING INK *and of the materials entering into its composition;—and one who has devoted the greater part of his life to the advancement of good printing in all of its many branches, and who today is acknowledged Dean of the Printing Ink Fraternity.*

by

FRANK BESTOW WIBORG

CONTENTS

ILLUSTRATIONS

ACKNOWLEDGMENTS OF CO-OPERATION

IT gives the writer much pleasure to express his very sincere appreciation of the valuable aid afforded him by the courteous assistance of various persons, particularly the following: Berthold Laufer, Ph.D.; Doctor Martin Ornslow Foster, F. R. S.; C. Harold Smith, Manufacturer and high authority on Lampblack and Carbon Blacks; W. W. Mock, Ph.D., M. Sc.; E. M. Van Dyck, Chemist and Printing Ink Specialist; Robert F. Salade, Technical Writer on Printing Subjects; Stephen H. Horgan, Pioneer Photo-Engraver and Author; E. H. McLeod, Chemist and Printing Ink Specialist; Charles F. Hart, Prominent Newspaper Pressroom Executive; Frank Wright, Chemist—Ink and Colors; Clarence A. Steinmetz, Secretary.

Acknowledgment is also due to twenty or more ancient and modern writers on Printing Ink subjects quoted throughout this work and who have aided materially in making it possible.

The Bibliography reviews in detail some of the more important authors and their writings to whom the writer is indebted.

This volume is offered to the public hoping thereby to give some useful information on a subject not heretofore recorded, or any way appearing in this form, trusting it may meet the approval of Printers generally and supply in some measure a long felt want—a comprehensive story of Printers' Ink from the beginning to

INTRODUCTION

THERE can be no question that the crude pictures of the Stone Age were the first efforts of man to make an enduring record of his achievements and the events of his daily life. The papyrus of Egypt, the clay cylinders of Babylon and other ancient methods of preserving records were steps in the general progress of the world. When we carefully consider the importance of a proper preservation of human activities in science, literature, history and government, including the daily records of every progressive effort and accomplishment connected with modern life, the first place must be accorded, or suggests from the writer's point of view, the present time as the Golden Age of Printing, in which Ink plays an important part.

The remarkable progress made in the last century in the art of printing has paralleled that of any other art or science. Today the judicious use of printing by advertising and other direct methods is developing many great industries and helping to create romantic fortunes that will be perpetuated by it in history.

The well-known Henry Lewis Bullen has testified to its place in man's progress in a lecture, November 14, 1924, under the auspices of the London School of Printing: "The Art, and mystery of the Art of Printing is to mankind and civilization vitally important—supremely important. The history of the art of printing is the history of all Civilization. Without the aid of it there would have been no Stephenson, no Raphael, no Watt, no

Michelangelo, no Marconi, no Wright to give us the flying machine, and no Edison. Printing is the only art that serves mind, soul and spirit. And it is the only art that can widely communicate abstract ideas upon which all spiritual and mental progress depends."

The printing industry to 1926, including in its scope newspaper, book, magazine and general publication work, as well as commercial printing in all its branches,—letter press, steel and copper plate, and all the ramifications of the printing art—is rated in Government statistics as the fifth great industry in America. It is rapidly increasing and in all probability will have a higher rank within the next decade. It has approximately the same relative position in the industrial interests of the entire world; in England it holds at present perhaps even a higher place among the industries than in America.

Printing Ink, or the reproducing vehicle of which we are treating, is a rather small thing compared with the other necessary equipment of a modern printing industrial plant. There are today perhaps a hundred or more different methods of printing, in every one of which printing ink plays its own particular part. In comparison with the other essentials, such as presses, paper, type, engravings, electrotypes, the makeup of type forms, rollers, and all other important items of this group, the cost of the ink is small, often insignificant.

Writing a history of printing ink today, going back to the origin of its earliest use, involves references to the crude markings of one substance upon another to produce a line or figure. The origin of ink is still a matter of dispute, as ancient records differ. The chapters contributed to this book by Dr. Berthold Laufer, Curator of Anthropology, of the Field Museum of Natural History, Chicago, come from an authoritative source. He stands pre-eminent in his high profession.

With some hesitancy this work has been undertaken, with no purpose of assuming the prerogative of self-appointed historian for the industry, but having been actively engaged as a manufacturer of printing inks, varnishes and dry colors for more than a third of a century, has emboldened the writer to take the step. His experience, associations and studies, in North and South America, England, and the Orient, but particularly in the United States, are justification for presenting to the world the facts gathered together in this book pertaining to the important art of making Printing Ink.

So rapid are the changes that take place in the art of printing and so much is demanded of ink, paper and other agencies that is novel and complicated, that a technical book five years old may be obsolete today. William Savage in 1832 wrote a history of Printing Ink in which he said: "The process of making Printing Ink has never yet been treated of fully by any practical man, either printer or manufacturer, so that this work will come before the public on a subject as new as it is important." In the century that has since elapsed, the manufacture of Printing Ink has been revolutionized and so changed that his statement is as applicable today as it was then.

David N. Carvalho's *Forty Centuries of Ink,* 1904, states: "History has not given us the names of ancient ink makers, but we can believe there must have been during a period of thousands of years a great many, and that the kinds and varieties of inks were without number. Those inks which remain to us are to be found only as written with on ancient MSS.; they are of but few kinds and in composition and appearance preserve a phenomenal identity, though belonging to countries and epochs widely separated. This identity leads to the further conclusion that ink-making must have been an industry at certain periods, not overlooked by careful compounders who distributed their wares over a vast territory but unrecorded."

The manufacture of printing ink today means more than the simple compounding and grinding of lampblack or pigments of various colors in an oil vehicle or varnish. Excellent lampblack and pigments of different varieties and grades, as well as varnishes and driers, can be bought from regular manufacturers of such products in this country and abroad. This has induced a few concerns to enter the industry and announce themselves as "ink manufacturers," using the phrase in a sense that hardly covers the case.

During the early part of the twentieth century, printers were in the habit of making their own inks and selling the surplus product to other printers. The greatest competition which the legitimate ink manufacturer has today is from the small compounder who makes prices oftentimes which the manufacturer with his extensive plant, testing laboratories, research equipment and accompanying overhead charges, cannot meet except at a loss. The same is true of the amateur printer, possibly an apprentice, who works at home during leisure hours and produces small job printing, such as letterheads and cards in competition with the legitimate printer organized for regular commercial purposes. It is just as difficult for well-established printing firms to compete in price with the amateur printer as it is for regular ink manufacturers to compete with the "amateur ink maker."

In behalf of quality, it behooves the careful printer to purchase ink from reputable manufacturing houses of long and varied experience, who may be considered entirely reliable and responsible in furnishing the best possible product.

There are about 105 printing-ink manufacturing firms in the United States today, according to the present roster of the Secretary of the National Printing Ink Makers' Association. New establishments are frequently founded but often short lived. There are equally as many ink manufacturers in England and continental Europe, totalling at the lowest estimate 200 manufacturers of ink throughout the world. These many large plants show the tremendous increase in this industry since its beginning.

In the chapters describing the important modern methods of printing, I have given the facts and figures from the best sources available. If any misstatements have crept in through oversight or lack of full information, I shall endeavor to correct them in a second volume to be published in , in the meantime asking forgiveness for any errors committed as being from the head and not from the heart.

FRANK B. WIBORG.

PRINTING INK

"Ink is the great missive weapon
in all battles of the learned. . . ."

JONATHAN SWIFT.

CHAPTER I

THE HISTORY OF INK IN CHINA

THE celebrated calligrapher Wang Hi-chi (A.D. 321-379), whose handwriting is said to have been "light as floating clouds and vigorous as a startled dragon," is credited with the dictum, "Paper represents the troops arrayed for battle; the writing-brush, sword and shield; ink represents the soldier's armor; the ink-stone, a city's wall and moat; while the sentiments of the heart symbolize the chief commander." In this saying the mental attitude of the Chinese toward the arsenal of the learned is well crystallized: paper, brush, ink, and ink-slab are the four great emblems of scholarship and culture, inventions which the Chinese may justly claim as their own, which constitute the fundamentals of their civilization, and which have largely contributed to make them a nation of studious, well-bred, and cultured men.

In extolling the art of printing as one of the great achievements which has remodelled our intellectual life, we must not overlook the fact that the merit of this invention rests to a lesser degree on the basic idea than on its primary conditions,—the existence of an economic material suitable for writing and printing and easy to manufacture in large quantity, and a medium that will permanently fix the written thought to the paper. That rag-paper is a Chinese invention and that the Arabs transmitted the method of its manufacture to Europe is a fact established beyond any doubt, not only through historical records, but also through archæological discoveries and microscopical and chemical analyses of ancient paper remains.

The same cannot be said about ink: Egypt, the ancients, and mediæval Europe were familiar with ink of different kinds; but the Chinese product is so superior to anything accomplished in the West that for centuries it was employed by artists of Europe under the misnomer "India ink," and is still unrivalled.

The date for the first manufacture in China of ink in the proper sense of the word is variously given in current literature. Palladius, a prominent Russian sinologue, writes that ink is said to have first been produced in A.D. 220; and Geerts (*Les produits de la nature japonaise et chinoise,* 1878, p. 197), in accordance with S. Julien, gives the date more specifically as that of the Wei and Tsin dynasties (A.D. 220-419). This indeed is the period commonly fixed in Chinese sources. In consequence of a misprint in M. Jametel's little book *L'Encre de Chine* (1882, p. xi), where the date of the Wei is given as "220 à 260 [instead of 265] avant [instead of après] J.-C.," several authors have adopted the error in assigning the invention to the third century B.C. Thus F. M. Feldhaus (*Technik der Vorzeit,* 1914, col. 1198) and Rein (*Industries of Japan,* p. 417) even turn the figures around, giving 260-220 B.C. as the date for the invention of ink. Giles (*Glossary of Reference on Subjects connected with the Far East,* p. 132) states that ink was used all over the empire since the third century of our era, though, according to one native authority, it was manufactured as early as 140 B.C.

While Chinese records give us a name for the inventor of rag-paper and the writing-brush, there is no name on record for the inventor of ink, simply for the reason that ink is not the invention of an individual. The situation is the same as that with regard to porcelain: Porcelain is not an invention that can be attributed to the efforts of an individual; but it was a slow and gradual process of finding, groping, and experimenting, the outcome of the united exertions of several centuries and generations. The same observation holds good for the history of ink. It took the Chinese several centuries of tests and trials until they eventually discovered an acceptable formula for a good ink, and even after this discovery they made constant improvements and developed the method, as they also enlisted new materials. It is one of the outstanding examples of progress in Chinese technology and an eloquent refutation of the dogma of the stationary character of Chinese culture.

If, in accordance with Chinese conception, ink properly so-called was only the result of the labors of the early middle ages (third to the beginning of the fifth century A.D.), our historical inquiry is mainly concerned with three questions: (1) What were the writing-materials in the times of the earliest antiquity of China? (2) What was the medium of writing in the age of the closing antiquity (period of the two Han dynasties, 209 B.C.-A.D. 220), when the writing-brush and finally paper (from A.D. 105) existed? (3) What did the invention of the Wei and Tsin periods consist of, and how was it further developed?

In a certain class of popular Chinese books of recent date whose main object it is to trace the history of cultural objects and inventions, and which have the undisguised tendency to advance them as far as possible into the dim past, it is boldly asserted that the beginnings of ink and ink-slabs go back into the mythical days of the emperor Huang-ti (alleged date 2698 B.C.), and some even give as the name of the "inventor" Tien Chen, supposed to have lived at that time. No such tradition exists in any ancient book as the *Chu shu ki nien* (*Annals written on Bamboo Tablets*) or the *Shi ki* (*Historical Memoirs*) of Sema Ts'ien. This modern construction is purely fictitious and arbitrary, and is contradictory to all historical facts known in the case.

In a prehistoric age we find knotted cords in use for the conveyance of messages, chiefly in the transaction of government business. Lao-tse, the famed philosopher, in a sentimental yearning for the past, expressed the desire that he might bring his people back to the ancient usage of knotted cords; that is, the simple life of old. The Tibetans have a tradition to the same effect, and certain aboriginal tribes in the south of China availed themselves of this method as late as the twelfth century A.D. In early historic times calendars, calculations, and contracts were made by means of wooden tallies in which notches were carved with a knife; the creditor, for instance, received the left; the debtor, the right half of the tally. Under the Shang dynasty (1783-1123 B.C.) bone and tortoise-shell served as the conveyance of writing, the characters being slightly incised in the surface; such bones were chiefly inscribed for purposes of divination, and many have been unearthed during the last two decades. The earliest form of Chinese script is preserved on them. Further, we have from the early dynasties inscriptions on bronze vases and bells, the writing being produced in the wax mould, and being either incised or raised. Tablets of jade were used for writing by the emperor; tablets of ivory, by the nobles and higher officials. The most common material, however, particularly under the Chou dynasty (1122-247 B.C.) consisted of bamboo slips or square wooden splints which were perforated at their upper ends and fastened together by means of a silk cord or fine leather strip. The main difference between the utilization of bamboo and wood was this, that a message containing upwards of a hundred words was written on bamboo slips; when it contained less than a hundred words, on wooden boards. The bamboo tablets were naturally narrow, and could be piled up in any required number formed into a pack. The wooden documents, being too heavy to allow of a combination of many, served only for brief texts, as official acts and regulations, statistics of the population, and prayers, but they could not be united into books.

The early canonical literature was handed down on bamboo slips of different lengths, each slip as a rule containing a single line of writing varying from eight to twenty-five or thirty words, and inscribed on one side only. Such books, of course, were exposed to many causes of destruction, chiefly from humidity and pernicious insects, so that bamboo books of early antiquity have long since disappeared. Another inconvenience of these books was their heavy weight. A curious incident in allusion to this fact is recorded anent the emperor Ts'in Shi, who was compelled to examine daily state documents to the weight of a hundred and twenty pounds. Neither writing-brush nor ink was invented in those early days, and the bamboo and wooden memoranda were inscribed by means of a pointed bamboo or wooden stylus (*pi*) dipped in a black varnish (*ts'i*). The bamboo or wooden stylus has survived in Tibet and among several other tribes akin to the Chinese. Varnish, according to the unanimous opinion of all competent scholars of China, was the earliest vehicle of committing thoughts to writing. What the composition and preparation of this ancient varnish was, however, is not known; but it is more than probable that it was a product obtained from the sap of the lacquer or varnish tree (*Rhus vernicifera* D. C., family *Anacardiaceæ*), a sumach indigenous to China. In fact, this tree is designated by the same word *ts'i* as applied to the varnish used in writing. The corresponding Tibetan word *r-tsi* denotes any thick vegetable sap, varnish, or paint. The tree was cultivated by the Chinese in ancient times; in the Book of Songs (*Shi king*) it is mentioned three times, in one case as having been planted by Duke Wan. In superior quality its varnish was produced in Yü-chou in the province of Ho-nan and in Yen-chou in the western part of the province of Shan-tung, as may be gleaned from the chapter Yü kung inserted in the *Shu king* (*Book of Historical Records*).

In the *Chou li,* the State Handbook of the Chou dynasty (1122-247 B.C.), varnish is referred to as being applied to bows, to spikes of chariot-wheels, and to hides used for drums. The fact that it was regarded as a precious substance becomes evident from the Book of Rites (*Li ki*), which says that it was employed for coating the covers of the coffins of princes and the highest officials, but that this privilege was not conceded to plain officials. When a prince ascended the throne, his coffin was made and stored away, a coat of varnish being laid on once a year. The Chinese character for the tree consists of the symbols for wood and water written one above the other, alluding to the sap oozing out and dripping down the trunk. The varnish is extracted by making a horizontal slit upon the tree, and this can be done throughout the warm season, from April to the end of October. The varnish released in the spring is least valuable, because it is very watery. The autumn product is much thicker, but also granulous and slow in exudation. Midsummer is the best time for the harvest, and the varnish is then at its best as to quality and quantity. The tapping, as a rule, begins when the tree is from nine to ten years old. The tree was introduced from China to Japan (Japanese *urushi-no-ki*), where it is eagerly cultivated for the same purposes as in its mother country—the preparation of a lacquer from the sap.

There is direct testimony for the fact that books written on bamboo or wooden tablets by means of varnish were actually produced. In A.D. 279 a tomb was opened at Ki in the prefecture of Wei-hui, province of Ho-nan, and yielded several ancient manuscripts of which we have a contemporaneous record: it is stated that they were written with varnish in "tadpole" characters, an ancient form of script. On the other hand, it is reported that one of the manuscripts discovered in the tomb of Ki, and interred there in 299 B.C., the famous *Mu t'ien tse chwan* (the romantic narrative dealing with King Mu's travels to the west) was written on bamboo slips, each containing forty words, with ink (*mo*); and this is the word still used for "ink." This word appears frequently during the Han period (209 B.C.-A.D. 220), and even a few centuries earlier.

Chou Sho, the councillor of Chao Kien-tse, who died in 458 B.C., said to his master, "With my brush [*pi*] soaked in ink [*mo*] and the tablet held in my hand I shall watch over the faults of your highness." In the Annals of the Later Han Dynasty we read of large and small pieces of ink, and even the term "paper and ink" (*chi mo*) occurs. In view of this fact it is curious that the majority of Chinese scholars who have made ink the subject of special research are agreed on the point that ink in the modern sense was made but as late as the age of the Wei and Tsin dynasties; that is, the period from A.D. 220-419. In order to understand and reconcile these anomalies it is necessary to scrutinize the subject at closer range.

The word used throughout the centuries and still at the present time for the designation of writing and printing ink is *mo* (ancient form *ma-g,* Canton *mök,* Amoy *bat,* Yün-nan *muk,* Korean *mik,* Japanese *moku* or *boku*). The question arises, what notion was conveyed by this word in times prior to the invention of real ink? The etymology of the word gives no direct response to this query. Its primeval and fundamental significance is "black, dark, obscure"; and in this sense it is used in a passage occurring in the work of the philosopher Mong-tse (called Mencius) in the fifth century B.C., where the face of a minister is described as deep black (*shön mo*). From a comparative viewpoint ancient Chinese *mag* corresponds to Tibetan *nag* ("black"), *s-mag* ("dark"), and *s-nag* ("ink"), which goes to show that both in Chinese and Tibetan the word "black" has assumed the meaning "ink," as soon as the invention of ink was made; in fact, the word *nag* or *mag* (thus in some Karen dialects) for "black" is common to all Indo-Chinese or Sinic languages.

In consulting the written symbol or character for the Chinese word *mo,* we find that it is not a simple, spontaneous formation, but presents a composition of two well-known signs, those for "black" (*hei,* anciently *gag*) and "earth" (*t'u,* anciently *du*). The meaning connoted by the character, accordingly, is "black earth" or "black clay," and may hint at the fact that a mineral or clayish substance of black color may be hidden under this term. This opinion is indeed advanced by Chinese writers. Thus Li Shi-chen, author of the famous herbal *Pen ts'ao kang mu* in the latter part of the sixteenth century, infers from the formation of the character for *mo* that the ink of the ancients was made from black earth (*hei t'u*), referring also to the definition in the ancient dictionary *Shwo wen* (about A.D. 100) that *mo* is a kind of earth formed by smoke and glue. It must be borne in mind, however, that any such conclusions as to material, merely deduced from the construction of written symbols, are usually fraught with danger or may be deceptive, that the present explanation is more or less an afterthought, and that the old contemporaneous tradition is lost.

Several passages in ancient texts show us that *mo* was a black pigment. The philosopher Mong-tse, mentioned above, speaks in another chapter of his work of the carpenter's marking-line, expressing it by the compound *sheng mo* ("string and ink," or more cautiously "string and black substance *mo*"). It is clear that the carpenters of his time, in the same manner as those of the present day, must have availed themselves of an instrument for marking lines in black.

Another instance of the ancient application of the word *mo* occurs in the penal code of the Chou dynasty first issued on bamboo slips in 501 B.C. in which five kinds of punishment are laid down, the first of these being branding of a criminal's forehead. This process is denoted by the term *mo,* which in this case is imbued with verbal force ("to blacken, to brand"). We are not informed as to what this black pigment used for the mark of infamy was; it was applied to the forehead by means of an incision with a cutting instrument, and must have been of a rather indelible nature (cf. Couvreur, *Chou king,* p. 386).

Among the ancient Chinese the tortoise was one of the principal vehicles of divination. The carapace of the animal was coated with a layer of a black pigment (*mo*) and exposed to a fire. Thereupon the delineations of the cracks produced by the action of the fire were examined, and the will of Heaven was read from them. This process was styled *ting mo* ("to determine the pigment": Couvreur, *Li Ki,* Vol. 1, p. 682). It was the rule, however, to burn the tortoise-shell without the application of a pigment.

The invention of the writing-brush must have acted as a stimulus to the improvement of all writing materials. Traditionally, the brush is credited to Mung T'ien, who served as general to the first emperor Ts'in Shi, and who died in 209 B.C. This tradition, however, is to be taken *cum grano salis*. It is not recorded by a serious historian like Se-ma T'sien, whose *Shi ki* is the chief source for the history of that emperor's reign; and some Chinese authors are inclined to think that the invention of the brush was merely attributed to Mung T'ien for the glorification of his imperial master, who wished everything to begin from his reign. It would be absurd to assume that the general was the first Chinese who ever invented a brush; so simple an implement must doubtless have existed centuries before his time.

The eminent scholar Yen Shi-ku (A.D. 579-645) probably hits the truth with the following comment: "The tubes of the ancient writing-brushes were made from dried wood with deer's hair backed by sheep wool, but there were no bamboo tubes with hare's hair; this was the work of Mung T'ien." In other words, Mung T'ien may have applied two improvements to the writing-brush, which itself pre-existed; he made it lighter in weight, with finer hair, and perhaps more elegant in form. If he really had anything to do with the whole affair, it is striking that an instrument exalted by the literati and essentially one of the learned owed its perfection to a man of the much despised military class; or, we might rather say, it is surprising that popular imagination, in seeking for the inventor of the writing-brush, has fastened the honor on an old general who is not known as a writer.

Another important innovation took place in the third century B.C., presumably under the Ts'in dynasty (246-207 B.C.), when a paper made from silk refuse including both raw and woven silk came into being. This silken paper was preceded by bands of silk stuff serving as writing material. The refuse from silkworm cocoons was soaked and beaten in water in order to eliminate coarse particles. This mass was reduced to a paste, and thus purified was spread over a fine bamboo mat mounted on a wooden frame. This served as the mould on which the paste precipitated, and when dried, produced a sheet of paper. Such bamboo mats are still utilized in the modern manufacture of paper from bamboo or tree-bast fibres.

It is clear also that the underlying principle of the subsequent manufacture of rag-paper was forestalled by that of silk paper. Since the writing-brush was perfected in the same period, we can hardly call this coincidence accidental, but must admit that the two inventions were dependent one on the other; hence the further conclusion is justified that the two again may have stimulated the production of a better expedient for writing, which resulted in the black pigment called *mo*. At the outset it is not very likely that varnish continued for silk material and silk paper, nor is it likely that the ancient wooden stylus was applied to silk. Thus there are good technical reasons for the conviction that the varnish of early antiquity was gradually replaced by a more convenient substance in the three or four centuries preceding our era.

A still more powerful impetus to the improvement of writing-ink was received from the invention of bark and rag paper by Ts'ai Lun in A.D. 105. Ts'ai Lun was born at Kwei-yang, a city of Kwei-chou Province in southern China. In A.D. 75 he entered the service of the emperor Ho, and in 89 was appointed director of the imperial arsenals. He was deeply given to study, and whenever he was off duty, he would shut himself up for that purpose. He survived his invention for thirteen years, being ennobled as marquis in 114. In the same year, however, as he could not find favor with the empress, he died a suicide by swallowing a dose of poison. Ts'ai Lun considered that both silk and bamboo tablets were inconvenient writing-materials, the former being too expensive, the latter too cumbersome and perishable. Hence he conceived the idea of using bast-fibre, hemp, and old rags like fishing-nets for making three kinds of paper.

This invention created a profound impression on the contemporaries, who at once turned it to practical use. Although Ts'ai Lun perpetuated and advanced a pre-existing process, and his principal merit consisted in the substitution of little valuable or even valueless substances, which simultaneously yielded better results, for the comparatively costly silk-refuse, he must be honored as the man to whom we are indebted for one of the most far-reaching discoveries ever made in the annals of technology. Without paper there would have been no adequate record of the past, no progress, no science; it marks the dawn of civilization, it sets off civilization from savagery.

Thus the life of the Han dynasty, during the last century of its existence, was signally enriched by the acquisition of paper. Nevertheless, in the outlying colonial possessions, the use of wooden tablets persisted with conservative force. A great number of these were rescued from the sand of Chinese Turkestan by Sir Aurel M. Stein, and have been edited and translated by E. Chavannes (*Les Documents chinois découverts dans les sables du Turkestan oriental,* Oxford, 1913). The wooden slips studied by Chavannes range in date from 98 B.C. to A.D. 153. He observes that a goodly number of these are inscribed with characters of extreme *finesse*, and that their delicate traits could have but resulted from the use of a brush; unfortunately he is silent as to the ink. In the reproductions of the documents the writing appears in black ink, in appearance not different from the Chinese ink to which we are accustomed. This, of course, does not mean that the Han ink might not have been an entirely distinct affair. Microscopical and chemical analysis would be the only means of solving the problem, and it is hoped that the authorities of the British Museum will consent to having this investigation made some day.

Meanwhile, we are thrown back on Chinese literary sources. It is certain that in the Han period an ink-like substance for writing, called *mo*, was utilized; but what its composition was, is not revealed. No recipe has been handed down from that epoch. The fact that it was different from the later ink is manifest from the persistent tradition that this product made its appearance only under the Wei and Tsin. Ch'ao Shwo-chi of the Sung period, who wrote an interesting treatise on the technology of ink, opens it by saying that formerly two kinds of ink were in use,—one prepared from pine-tree lampblack (*sung yen*), another styled "mineral ink" (*shi mo,* literally "stone ink"). The latter, he comments, has disappeared since the Tsin and Wei periods, but he does not explain what it was. He assumes that under the Han period ink was also manufactured from pine charcoal, as *Yü-mi mo* ("ink from Yü-mi") is mentioned at that time, and the Chung-nan mountains at Yü-mi (in Shen-si Province) were covered with pines; but this is a theory which remains in the realm of conjecture.

T'ao Tsung-i, who wrote the *Cho keng lu* in A.D. 1366 (under the Yüan dynasty), states that in times of earliest antiquity there was no ink, documents being written by means of a piece of bamboo dipped in varnish, and that in the middle period of antiquity they utilized the sap of *shi mo,* which is believed by some to be identical with the stone of Yen-ngan in Shen-si (that is, rock-oil or kerosene). This mineral product is described by the Chinese as a stone grease floating on the surface of water, like varnish, and collected to be burnt in lamps or made into torches. From the Sung period onward the lampblack from petroleum was used in the manufacture of ink, called *Yen ngan shi i* ("secretion from the stone of Yen-ngan"), these words being engraved on the ink-cake.

It is on record that Lu Ki or Lu Shi-heng, who lived in the latter part of the third century A.D., one day ascended the T'ung ts'iao t'ai ("Copper Sparrow Terrace"), a tower built by the famed Ts'ao Ts'ao in A.D. 210, and found several jars full of *shi mo* collected and stored by Ts'ao Ts'ao, such as existed no more at any later period. Subsequent authors indulged in speculations as to the material contained in these jars. In this case it is again assumed by some that this substance was identical with the lampblack produced from kerosene (*shi chu yen,* "stone torch smoke") in Shen-si, mentioned by Shen Kwa in his *Mong k'i pi t'an,* written in the middle of the eleventh century. It is supposed also that the cosmetic used for painting the eyebrows by the women of the palace of the Sui dynasty (A.D. 583-617) was a kind of *shi mo.*

Under the term *shi mo* quite a number of different minerals appear to be confounded. *Shi mo* is also a synonym of *shi tan* ("mineral coal"), and Li Shi-chen (*Pen ts'ao kang mu,* Ch. 9, p. 20) affirms that in times of antiquity bituminous coal was utilized for writing. The possibility of this cannot be denied. Incidentally, one Chinese author declares that lead was anciently used for writing.

Several minerals were formerly utilized as substitutes for ink. The *Yün lin shi p'u*, a treatise on economic mineralogy written by Tu Wan (pseudonym Yün-lin) in A.D. 1133 (Ch. 3, p. 11b), says that in Kwei-chou (prefecture of I-ch'ang, Hu-pei Province) there are black stones appearing in the water of the Yangtse River, of coarse substance, which can be ground and will yield an ink. This stone is called *ta t'o shi* ("stone of the great river"), *t'o* being the local name for the Yangtse among the inhabitants of the gorges near I-ch'ang, who prize this stone very highly. This same work mentions a stone of Ts'ing-chou in Shan-tung, found deep in the soil, being carved and ground, not containing much ink, but used locally. A "dragon-tooth stone" (*lung ya shi*), according to the same author, is found in the district of Ninghiang in the prefecture of Yo-chou, Hu-nan Province, both in water and in the mountains, of purple color, somewhat glossy, capable of being ground into ink and rather appreciated by the people of the place. Finally, in the river of the district of Fen-i in the prefecture of Yüanchou, Kiang-si Province, occurs a stone, dark in color, hard and bright, sonorous when struck, gathered by the natives in the water, and ground into ink, which is suitable for the brush; but the material is so coarse that instruments for cutting and grinding it are required. For Kwang-tung Province mineral ink mountains furnishing writing-ink of excellent quality are mentioned as early as the Tsin period in the *Kwang chou ki* of Ku Wei.

There is another kind of *shi mo,* which is identified with *hei shi chi* ("grease of black stone"), described as sticking to the tongue when licked and used for writing, as well as for painting the eyebrows (much practised in ancient China). This is doubtless graphite (Geerts, *Produits*, p. 203). F. de Mély (*Le lapidaire chinois*, p. 256) is inclined to take it for "sulfure d'antimoine." Now the term *shi mo* in the sense of graphite occurs for the first time in the early work *Pie lu,* the foundation of which goes back to at least the Han period, and possibly even to an earlier date. This would well indicate that graphite was one of the substances enlisted as writing material in the epoch of the Han. Besides, products of mineral coal, bitumen, and rock-oil may have been utilized; the earliest ink, accordingly, was of mineral origin, in opposition to the vegetable products laid under contribution in the following period, under the Wei and Tsin (A.D. 220-419).

The oldest recipe for the preparation of an ink that has come down to us is contained in the *Ts'i min yao shu,* a work on practical husbandry, written by Kia Se-hie, who lived in the fifth or sixth century A.D. Unfortunately this important work is handed down in mutilated form. The original was in 92 sections, part of which were lost long ago, and much additional matter has been interpolated by subsequent editors. The recipe for ink, entitled "Method of mixing ink," is apparently incomplete, since the substance from which the lampblack is derived is not even mentioned; in some places the text is enigmatic and evidently corrupt.

Ch'ao Shwo-chi, an author of the Sung period, who wrote a very interesting treatise on the manufacture of ink, quotes three passages from the recipe of Kia, but his text is different from that found in the present editions of the *T'si min yao shu.* The principal points of the formula are as follows: Good and pure lampblack is to be pounded and strained through a sieve of fine pongee, which is placed in a vat of stoneware. The object of this process is to free the lampblack of any adhering vegetable substances so that it becomes like fine sand and dust; but as it is so light in weight, great care must be exercised in preventing it from being scattered around. Five ounces of glue are required for one pound (catty) of ink, and the sap of the bark of the *ts'in-p'i* tree (*Fraxinus pubinervus*) is dissolved in the glue. This bark is green in color like water, and contains a glutinous substance which also improves the color of the ink. The white of five hen's eggs, one ounce of cinnabar, and the same amount of musk may likewise be added, after being well strained. All these ingredients are mixed, and the paste thus obtained must be beaten in an iron mortar with a stick thirty thousand times; the more frequently it is beaten, the better the quality of the ink. In weight a cake of ink should not exceed two or three ounces, and its size should conform to this rule; that is, it must be small, not large.

However imperfect this formula may be, it leaves no doubt that it carries the directions for a real ink, and that in principle it is identical with the process still in vogue. Even though the source of the lampblack is not clearly indicated, it follows from the context that it was of vegetable origin. Li Shi-chen, the great herbalist at the end of the sixteenth century, states expressly that the best ink in his time was made from lampblack of pine-wood with an admixture of the sap of *Fraxinus pubinervus*, boiled together with glue as well as aromatic substances. The green bark of this tree steeped in water is still utilized for obtaining a bluish indelible ink.

It is obvious that the formula divulged by Kia Se-hie did not spring up spontaneously, but that it presents the result of long experiences and experiments conducted during several generations. In fact, he had predecessors, as we see from the *Mo king* of Ch'ao Shwo-chi of the Sung period, who quotes the "ink method" of Wei Tan or Wei Chung-tsiang of the Wei dynasty (A.D. 220-264); this author has also the thirty thousand beatings—doubtless an exaggeration. Coming down to the T'ang dynasty, Wang Kiün-te, an ink manufacturer, who used a stone mortar, speaks more moderately of from two to three thousand beatings. Under the Ming, toward the end of the sixteenth century, a wooden mortar with a metal pestle was employed, and one was satisfied with several hundred beatings. There is every reason to believe that Wei Tan is the first originator of an ink-formula, as handed down in the *Ts'i min yao shu,* and to a certain degree may be regarded as the real inventor of ink as still manufactured. His name is the first which appears in the *Mo shi,* a history of ink manufacturers by Lu Yu of the Yüan dynasty, who observes that there is no great difference between the formulas of Wei Tan and Kia Se-hie. One of the former's peculiarities was that he mixed one ounce of genuine pearls and a half ounce of musk in his ink.

In the *T'ai p'ing yü lan* published by Li Fang in A.D. 983 (Ch. 605, p. 5) the recipe, as contained in the *Ts'i min yao shu,* is in fact quoted as that of Wei Tan, the text being substantially the same, with the one exception that his "ounce of cinnabar" is replaced by an "ounce of genuine pearls." We must therefore admit that Kia Se-hie merely copied Wei Tan. The latter lived from A.D. 176 to 251 to the age of 75. His ink was still renowned at the end of the fifth century. Siao Tse-liang, a prince of the Southern Ts'i dynasty (about A.D. 484), in one of his letters, speaks admiringly of "Chung-tsiang's ink, every drop like varnish!"

Chinese literature on ink is considerable. It begins to develop under the T'ang dynasty when a treatise on ink (*Mo king*) by Ch'eng Lao-po existed. This work, however, has not survived, but a few brief extracts are preserved in the *Yün sien tsa ki,* written by Fung Chi in the commencement of the tenth century, and in later works.

Several technical treatises on ink were written under the Sung, above all, the *Mo king* by Ch'ao Shwo-chi, which is reprinted in the great cyclopædia *T'u shu tsi ch'eng*. This author devotes a systematic discussion to the various kinds of pine-trees suitable for lampblack, with exact enumeration of the mountains and localities where they grow; then he has discourses on charcoal, glue, sifting, the processes of mixing and pounding, chemical ingredients, drying, grinding, color, sound, weight, new and old ink, preserving ink, proper season for making it, workmen and manufacturers.

Another treatise on ink, entitled *Mo p'u,* was published by Su I-kien at the close of the tenth century. The same author wrote a book on paper (*Chi p'u*), and in A.D. 986 summarized his experience in a comprehensive work which he called *Wen fang se p'u* (*The Four Departments of the Study*). This is a repository of information regarding the materials of the study, consisting of four parts which treat of writing-brushes, paper, ink, and ink-pallets, with historical memoranda, essays, and stanzas. Ho Yüan of the Sung wrote a *Mo ki* (*Ink Memoirs*) in which he deals with ink manufacturers; a long list of these from the T'ang to the Yüan dynasty is also inserted in the *Cho keng lu* by T'ao Tsung-i, published in A.D. 1366.

The most complete and interesting work of this class, however, is represented by the *Mo shi* (*Ink History*) of Lu Yu of the Yüan dynasty, who gives a series of brief notices of about a hundred and forty manufacturers whose names had been handed down in connection with their productions from the Wei, Tsin, T'ang and Sung dynasties down to the Kin. He also notes the ink of the Koreans, the Kitan, and Turkestan, with a number of miscellaneous observations respecting ink appended.

In the beginning of the Ming dynasty, in 1398, appeared a manual of the ink manufacturer, by Shen Ki-swan, illustrated by twenty-seven woodcuts showing the various stages in the process of manufacture. The author was a manufacturer himself and professes to divulge only the tricks of his own trade, save some information communicated to him by a monk. The little work teems with technical routine and detail, but in comprehensiveness and clarity does not compare with the *Mo king* of the Sung. It was first translated into Russian by I. Goshkewich (in Works of the Russian Mission of Peking, Vol. I, 1852; cf. W. Schott, Entwurf einer Beschreibung der chines. Literatur, p. 107), then from the Russian into German. A French translation with reproductions of the woodcuts is due to M. Jametel (Paris, 1882).

About 1637 Ma San-heng issued a *Mo chi* in which he treats of ink manufacturers with their productions and the marks that distinguish them. Kao Lien of the Ming wrote an essay, *Lun mo* (*Discourse on Ink*), and T'u Lung published the *Mo tsien,* a short work on ink, during the sixteenth century. The *Süe t'ang mo p'in* is a small treatise on ink, written by Chang Jen-hi in 1671, in which he classifies the productions of various manufacturers and points out the peculiar characteristics of the different kinds. The *Man t'ang mo p'in* is a similar record, supplementary to the preceding, written in 1685 by Sung Lao, who presents notices of thirty-four specimens of ink of the Ming dynasty, with their respective weights. Aside from such monographs there are innumerable references to ink in technological books like the *T'ien kung k'ai wu,* written by Sung Ying-sing in 1637, in the essay literature of the Sung, in cyclopædias, and in the herbals (*Pen ts'ao*).

While the Ming and Manchu dynasties hardly added anything new to the technical side of the subject, great care was bestowed on the artistic embellishment of ink-cakes, and we have several excellent books issued by ink-manufacturers giving reproductions of the designs engraved upon their ink-cakes. These will be considered in the next chapter.

CHAPTER II

THE HISTORY OF INK IN CHINA

(*Continued*)

AFTER this digression, let us revert to the history of ink. The poet Ts'ao Chi (A.D. 192-232) has left a verse in which he says that ink is produced by the smoke of the green pine. Now he was a contemporary of Wei Tan (A.D. 176-251), and it is therefore a reasonable conclusion that Wei Tan was the first who used the lamp-black from pine in the manufacture of ink. There is another formula handed down from the Wei period and attributed to a certain Ki kung (Mr. Ki) about whom nothing is known otherwise. His ink is said to have been made of two ounces of pine-black mixed with a little clove, musk, and dried varnish; this was compounded with glue, soaked in water, and heated over a fire, the entire process taking a full month; he produced inks of two colors,—a purple ink by adding the root of *Lithospermum officinale* L. var. *erythrorhizon* (the Chinese name of this plant means "purple herb"; it is still cultivated for the purple dye yielded by its root) and a bluish ink by using the bark of *Fraxinus pubinervus* (ts'in-p'i). Ink was formerly put up in various forms. The Chinese language has a large number of numeratives by which objects are counted, and the numeratives vary according to different categories of things and notions. Under the Han ink pieces were usually counted as so and so many *wan* (that is, "pills, pellets, balls"); ink being formerly taken as a medicine. It is very likely that it was first made into pills to be easily swallowed. This practice was continued under the Wei and Tsin, and under the T'ang also we occasionally hear of ink balls; but from that time onward this shape fell into disuse. It seems that in some out-of-the-way places ink is still made into balls; at least E. H. Parker (*Up the Yang-tse,* p. 135, Shanghai, 1899) reports that at An-si Ch'ang in Kwei-chou Province he saw exposed for sale balls of ink made from the soot of the *Aleurites* oil (wood oil or *t'ung* oil).

Further, ink pieces were formerly counted by *liang* (a measure of capacity) and, curiously enough, by conch-shells (*lo*), which may indicate that ink was kept in shells. An early author, T'ao Tsung-i, in A.D. 1366, asserts that in times after the Tsin there was a kind of ink called *lo-tse mo* ("shell ink"), as though shell powdered or burnt had formed an ingredient in its composition; but this notion surely rests on a misunderstanding, for the ancient texts contain nothing concerning such an ink, but what is spoken of is merely that someone, for instance, sent another "two shells of ink," which means ink of a quantity as two shells may hold, whether it was actually transmitted in shells or not.

The prismatic shape of ink seems to have come up under the T'ang: during his last exploration of Turkestan, Sir Aurel Stein (*Serindia,* Vol. 1, p. 316) discovered an octagonal prism of Chinese ink. On his previous journey he found in the stupa of Endere a "cylindrical piece of hard Chinese ink, drilled for a string at one end" (*Ancien-Khotan,* Vol. 1, p. 438). The prismatic or cylindrical shape (so-called sticks) has persisted to this day, and this is the form of ink destined for common use. It is, further, made into small, flat, rectangular cakes, sometimes also cast into circular forms if required by the artistic subject impressed upon the cake.

Under the great T'ang dynasty (A.D. 618-906) the manufacture of ink took an unprecedented development. Several events conspired to contribute to this result. Under the T'ang sovereigns Central Asia was annexed to the empire, and this political expansion led to the predominance of Chinese civilization all over Asia. Ink was required in the outlying dominions, whether politically dependent or merely under the influence of the Chinese culture-sphere. It was eagerly demanded in Turkestan as well as in Tibet; in Annam as well as in Japan. The same epoch marks China's Augustan age in literature and painting which then reached their climax, and above all, it was the new invention of printing books by means of wooden blocks which gave a fresh impetus to further progress in the production of ink.

At the end of the sixth century, under the Sui dynasty, when printing first became known, the imperial library contained some 37,000 books; in the early part of the eighth century, being the most flourishing period of the T'ang, the number of works described in the official record of the imperial library, amounted to 53,951 books, besides which there was a collection of recent authors, numbering 28,469 books. These figures will give an idea of the important function which paper and ink must then have performed in the national culture. Fortunately we now have at our disposal both manuscripts and prints of that epoch.

Woodcuts of the T'ang period have been discovered in the Cave of the Thousand Buddhas (Ts'ien Fu Tung) by Sir Aurel Stein (*Serindia,* p. 893) and Paul Pelliot. They illustrate, as Stein writes, the high stage of technique which the art of printing from wooden blocks attained comparatively soon after its first invention, and also the earliest use to which it is likely to have been put. A printed roll, dated A.D. 868 and containing in its 16 feet of length the complete text of a Chinese version of the Vajracchedika, is the oldest specimen of printing at present known to exist, and its fine frontispiece is the earliest datable woodcut. It shows Buddha seated on a lotus throne attended by a host of divine beings and monks and discoursing with his aged disciple Subhuti.

The first novel and significant departure in the age of the T'ang is the large number of ink factories springing up under the guidance of highly trained specialists. No less than twenty-five names of manufacturers of repute have been handed down from this epoch. In ancient times everyone was his own maker of ink, or the ink-maker was a man of no consequence. Under the T'ang, the business was taken out of private hands, and began to be industrialized and commercialized. With the vast expansion of the empire, governmental affairs increased in volume, and state correspondence assumed unparalleled proportions: thus the government was compelled to maintain its own ink establishments, and we hear of an "ink official" (*mo kwan,* or *mo wu kwan,* "official of ink affairs") who was placed in charge of the government works, under instruction to send an annual supply of ink to the metropolis for the feeding of the administrative machine.

The most famous of these ink directors was Tsu Min, whose reputation was widely known throughout the empire, and whose best ink was prepared with a glue concocted from deer's antlers; his fame was so lasting that even in the fourteenth century his name was still forged on ink-cakes. Another ink expert, Wang Kiün-te, worked exclusively for the imperial ateliers, and very little of his products reached the general public, so that any of his inks in private possession were looked upon as veritable family treasures and heirlooms. He availed himself of two sets of chemical accessories, one consisting of pomegranate peels preserved in vinegar, buffalo horn, and sulphate of copper; the other being composed of the bark of *Fraxinus pubinervus*, pods of *Gleditschia chinensis*, sulphate of copper, and *Verbena officinalis* (Chinese *ma-pien-ts'ao*, "horse-whip herb").

It is worthy of note that another species of Verbena is used in India for the manufacture of ink. The T'ang emperors also maintained an ink factory at Jao-chou in Kiang-si Province, where the slopes of the Lu Mountains (Lu shan) were covered with pines. It is on record that the emperor Hüan Tsung (A.D. 713-755) sent every season 336 pellets of ink to two colleges which he had founded, the T'u shu fu and Tsi hien yüan; and the same monarch is said to have himself manufactured an ink with the juice of lotus-flowers (*Nelumbium speciosum*) blended with an aromatic powder, his product being known as "imperial ink" (*yü mo*). This is a very interesting fact in that it demonstrates that the occupation of ink-making was then a perfectly honorable and even dignified and exalted profession, and this is no wonder in a society where learning was so highly esteemed and worshipped.

Most of the ink manufacturers of the T'ang were men of culture, literati and officials, and thanks to their social status, their names have come down to posterity. This is in striking contrast to the fact that, as known to everyone, China has produced a long line of ingenious and clever potters and bronze founders, men of humble standing, and that hardly any of their names have survived. We know and admire their works, but are ignorant of their names; of the ink artisans we have their names, not their works. In China, so far as is known, no ink-cakes of the T'ang and Sung periods are preserved; among the oldest are those which have come down from the Ming period. As regards the esteem in which the ink maker is held even in recent times, Du Halde states in his *Description de la Chine* (1738) that "everything which relates to writing is so reputable among the Chinese that even the workmen employed in making the ink are not looked upon as following a servile and mechanical employment."

In conformity with the specialization of work, the T'ang ink makers signed their pieces, covered them with inscriptions, and even provided them with a date. Thus under Kao Tsung (A.D. 650-683) was issued an ink bearing the inscription, "Ink guarding the treasury [*chen k'u mo*], made in the second year of the period Yung-hui" (A.D. 651). One of these pieces is said to have weighed two catties. There was another ink inscribed, "Made by Li Ts'ao, second secretary of the Board of Water Communication of the T'ang." Li Ts'ao was the ancestor of a family the members of which devoted their lives to the production of ink. They originated from Yi-shwi, but emigrated to Shö-chou which forms the prefectural city of Hui-chou in An-hui Province; extensive pine-tree forests in that locality induced them to choose it as their domicile. This region has remained the principal seat of the ink industry until the present time.

Of the various Li it was Li T'ing-kwei who attained the greatest fame. He was the "ink official" of the Southern T'ang dynasty (Nan T'ang, 937-975, also known as Kingdom of Kiang-nan, with Nanking as capital), and his products were regarded as the best in the empire and the goal which all subsequent manufacturers endeavored to reach; many also borrowed his name and counterfeited his ink-cakes. His originals usually bore an inscription consisting of four characters: *Li T'ing-kwei mo* ("ink of Li T'ing-kwei"); some also were dated, for instance, "In two sets of chemical accessories, one consisting of pomegranate peels preserved in vinegar, buffalo horn, and sulphate of copper; the other being composed of the bark of *Fraxinus pubinervus*, pods of *Gleditschia chinensis*, sulphate of copper, and *Verbena officinalis* (Chinese *ma-pien-ts'ao*, "horse-whip herb").

It is worthy of note that another species of Verbena is used in India for the manufacture of ink. The T'ang emperors also maintained an ink factory at Jao-chou in Kiang-si Province, where the slopes of the Lu Mountains (Lu shan) were covered with pines. It is on record that the emperor Hüan Tsung (A.D. 713-755) sent every season 336 pellets of ink to two colleges which he had founded, the T'u shu fu and Tsi hien yüan; and the same monarch is said to have himself manufactured an ink with the juice of lotus-flowers (*Nelumbium speciosum*) blended with an aromatic powder, his product being known as "imperial ink" (*yü mo*). This is a very interesting fact in that it demonstrates that the occupation of ink-making was then a perfectly honorable and even dignified and exalted profession, and this is no wonder in a society where learning was so highly esteemed and worshipped.

Most of the ink manufacturers of the T'ang were men of culture, literati and officials, and thanks to their social status, their names have come down to posterity. This is in striking contrast to the fact that, as known to everyone, China has produced a long line of ingenious and clever potters and bronze founders, men of humble standing, and that hardly any of their names have survived. We know and admire their works, but are ignorant of their names; of the ink artisans we have their names, not their works. In China, so far as is known, no ink-cakes of the T'ang and Sung periods are preserved; among the oldest are those which have come down from the Ming period. As regards the esteem in which the ink maker is held even in recent times, Du Halde states in his *Description de la Chine* (1738) that "everything which relates to writing is so reputable among the Chinese that even the workmen employed in making the ink are not looked upon as following a servile and mechanical employment."

In conformity with the specialization of work, the T'ang ink makers signed their pieces, covered them with inscriptions, and even provided them with a date. Thus under Kao Tsung (A.D. 650-683) was issued an ink bearing the inscription, "Ink guarding the treasury [*chen k'u mo*], made in the second year of the period Yung-hui" (A.D. 651). One of these pieces is said to have weighed two catties. There was another ink inscribed, "Made by Li Ts'ao, second secretary of the Board of Water Communication of the T'ang." Li Ts'ao was the ancestor of a family the members of which devoted their lives to the production of ink. They originated from Yi-shwi, but emigrated to Shö-chou which forms the prefectural city of Hui-chou in An-hui Province; extensive pine-tree forests in that locality induced them to choose it as their domicile. This region has remained the principal seat of the ink industry until the present time.

Of the various Li it was Li T'ing-kwei who attained the greatest fame. He was the "ink official" of the Southern T'ang dynasty (Nan T'ang, 937-975, also known as Kingdom of Kiang-nan, with Nanking as capital), and his products were regarded as the best in the empire and the goal which all subsequent manufacturers endeavored to reach; many also borrowed his name and counterfeited his ink-cakes. His originals usually bore an inscription consisting of four characters: *Li T'ing-kwei mo* ("ink of Li T'ing-kwei"); some also were dated, for instance, "In the first year of the period Pao-ta (A.D. 943) offered by Shö-chou and made by the official in charge of ink affairs, Li T'ing-kwei." His ink-cakes were four inches long, one inch wide, and one inch thick, and were frequently adorned with gilded dragons. They were as hard as metal and stone, and so hard and sharp that they could serve for smoothing printing blocks. Even after a hundred years, when rubbed, they still emitted an odor of camphor; and they yielded no sound in being rubbed on the stone, which the ancients always regarded as one of the criteria of good ink. A crackling sound was naturally caused by grittiness adhering in the ink, and good ink had to be free of any sandy matter. Other qualities demanded were that it should be deep black, light in weight, and extremely hard, its hardness being compared with that of jade.

In the palace the ink of Li T'ing-kwei was burnt, and the soot thus obtained was used as a paint for the eyebrows; it was hence styled "eyebrow-paint ink" (*hua mei mo*). His recipe was kept a secret and died with him. Ch'ao Shwo-chi, in his *Mo-king,* states that he availed himself of twelve chemical ingredients, but is only able to name four of them; these are gamboge, the inspissated sap derived from incisions into the bark of *Garcinia morella* or *G. hanburyi* (this beautiful reddish-yellow pigment is still used by Chinese draughtsmen and painters), rhinoceros-horn, genuine pearls, and the seeds of *Croton tiglium*. There is no doubt, of course, that lampblack of pine, as with all manufacturers of the T'ang period, formed the essential of his ink. He is also credited with the production of an ink of blue color.

Next in reputation to the ink of Li T'ing-kwei was that of Chang Yü from Yi-shwi, whose products were known as "tribute ink of Yi-shwi" (*Yi shwi kung mo*). He lived toward the end of the T'ang period, and his inks were made in the shape of copper coins, which was rather inconvenient for rubbing them. Another noted ink artisan was Chu Fung, who worked for Han Hi-tsai, a scholar and minister of state. His atelier at Shö-chou was known as the "hall where pine-trees are transformed" (*hoa sung t'ang*), and his ink was inscribed *Yüan chung-tse* or *Shö hiang yüe hia* ("musk moon box").

In the beginning of the T'ang dynasty (from A.D. 618) Korea (Kao-li) sent to the court of China an annual tribute of ink made from the lampblack of very old pine (*sung yen mo*) mixed with glue obtained from the antlers of the tailed deer (*mi lu, Cervus davidianus*). This Korean ink is described as black as if it were coated with varnish, glossy, and floating in water (*Wei lio,* Ch. 12, p. 1). It is sometimes asserted that the Koreans were the first who manufactured ink from pine lampblack, and that it was the Chinese who subsequently adopted the process; this conception of the matter, however, is not correct. The pine lampblack was utilized in China prior to the T'ang, probably as early as the third and fourth centuries A.D., and the Koreans learned the whole technique from the Chinese; but the Koreans succeeded in perfecting the product to a degree unknown in China by employing a particularly suitable pine-wood well dried in the course of years and a specially fine hart's-horn glue. The latter was known to the Chinese in early times, and is looked upon as the finest kind of glue (those next in rank being derived from the hides of horse, cow, rodents, and rhinoceros); it is called white glue (*pai kiao*) or yellow bright glue (*huang ming kiao*), the latter designation being also applied to the ink thus prepared. It was naturally expensive, as this glue was hard to obtain. The Korean product elicited the admiration of the Chinese, and for some time its method of manufacture remained a secret to them. They made several endeavors to imitate the art of the Koreans, but only attained the desired result toward the close of the T'ang dynasty (about A.D. 900); yet under the Ming the secret of making this ink was lost (*T'ung ya*, by Fang I-chi, Ch. 32, p. 17).

Under the Sung (A.D. 960-1279) we hear of several manufacturers who availed themselves of antlers' glue; thus, for instance, Chang Kü-tsing. Others, like P'an Ku, who lived during the latter part of the eleventh century, and who belongs to the most renowned ink manufacturers of the period, remodeled specimens of Korean ink by breaking them up, pounding the mass, and mixing it again with glue. P'an Ku is also noted for having used in his ink a sort of ivory-black made from bones.

The poet Su Shi, better known as Su Tung-p'o (1036-1101), prepared his own ink by using Korean charcoal and glue of the Kitan. When he lived as an exile on the island of Hai-nan, he caused P'an Heng to make for him an ink bearing the legend, "Hai-nan pine-tree charcoal, ink made after the method of Tung-p'o." This ink was presumably made according to the Korean method.

The Koreans were inventive and ingenious people, who not only advanced the cause of ink and conveyed its manufacture to the Japanese, but also improved on processes of paper-making and printing. They produced a very fine and durable paper from silkworm cocoons which achieved a great reputation in China, and they printed as early as 1403 with movable type cast of copper actual specimens of which may be seen in the American Museum of Natural History, New York. One peculiar custom of Korea, which may not have been practised in China or Japan, is particularly noteworthy: Ink-cakes were formerly offered by the emperor of Korea as a sacrifice to the gods, and there was attached to the Court a special department whose duty it was to manufacture this sacrificial ink. In the collections of Field Museum, Chicago, there is an old ink-cake coming from Korea, of oblong, rectangular shape. The obverse shows two dragons carved in high relief, two large characters being outlined in gold. They read *kwo pao* ("treasure of the country, national treasure"). The reverse contains an inscription in Chinese to the effect that this ink was made in the Yung-lo period (1403-25) of the Ming dynasty; but whether manufactured in Korea or China, is not stated.

Under the Sung a good many innovations as to detail were introduced, but the old principles virtually remained the same. Some improved on the lampblack, others on the glue, fish-glue was then first utilized, while others again devoted much thought and pains to the proper proportions and methods of bonding of the two. Shön Kwei, a native of Kia-ho in Hu-nan, produced a lampblack from charcoal of old pines which he blended with pine-resin and the sediments of varnish; this compound when burnt yielded an extremely fine lampblack which received the name "varnish-smoke" (*ts'i yen*).

The principal innovation that took place under the Sung was the substitution of vegetable, mineral, and animal oils for pine lampblack. The latter method continued in An-hui; the new method sprang up in the central and western provinces, notably Hu-nan and Se-ch'wan. It is clear that pine lampblack, after all, was a comparatively costly matter, that pine trees were not available everywhere, and that the ever-increasing demand for ink must have resulted in a despoliation of forests and contributed its share to that lamentable state of deforestation which has proved so grave a calamity to China. It is not surprising, therefore, that in view of the huge expansion of literature and art, writing, printing, drawing, and painting in the glorious age of the Sung, cheaper materials for the manufacture of ink were sought for.

Hu King-shun, a native of Ch'ang-sha (at that time called T'an-chou) in Hu-nan, obtained lampblack by burning the oil of *Aleurites vernicia* Hassk. (=*A. cordata* Steud., formerly *Elaeococca verrucosa* and *Dryandra cordata*); this was called "t'ung flower smoke" (*t'ung hua yen*) and proved a great success. His ink was much prized by painters for drawing the pupils of the eye. This oil, commercially known as t'ung oil or wood oil, is still accorded preference to any other in the modern manufacture of ink; a hundred catties of it yield eight catties of pure lampblack. Next in appreciation come the seeds of *Sterculia platanifolia* (*wu-t'ung*), which contain a good oil used in making ink. It is a stately, ornamental tree, frequently planted in the courtyards of temples and houses, its large leaves affording an excellent shade. It may be mentioned here that the juice from the crushed seeds is rubbed into gray hair, with the reputed virtue of causing the gray to fall out and the new hair to come in black.

In the period between A.D. 1067 and 1084, Chang Yü manufactured what became known as *yü mo* ("imperial ink"), as he presented his product to the Court. He used lampblack made from oil blended with musk, camphor, and gold-leaf, and is said to have been the first who availed himself of oil. His product was called *lung hiang tsi* ("dragon fragrance compound").

The oil-combustion ink seems to have at first roused the suspicion of some people, for an anecdote has it that when P'u Ta-shao produced his oil ink, people anxiously asked him how such ink could be strong and lasting; he assuaged the skeptics by responding that half of it contained pine lampblack, without which it could not be permanent. Whether this was correct or merely a subterfuge we do not know; it may be that such a "half-and-half" composition was really made, but it is certainly untrue that pine lampblack is necessary to give ink permanency. P'u Ta-shao was a native of Lang-chung, which forms the prefectural city of Pao-ning in Se-ch'wan Province, and his ink was widely used by scholars and offered as present to the throne.

K'ou Tsung-shi, author of the herbal *Pen ts'ao yen i,* written in A.D. 1116 under the Sung, has the following interesting account:—

"Ink is made from the black produced by the smoke of pine-trees. Our contemporaries manufacture a sham product from the ashes of grain stubbles, which should not be used. Only pine-soot ink is serviceable in the materia medica. Solely distant smoke is fine and yields an excellent product; the coarse one should be discarded. At present Korea dispatches ink to China with every mission of tribute, but the ingredients of this ink are not known, nor is it beneficial as a medicine. In Fu-chou and Yen-ngan fu (both in Shen-si Province) there is kerosene (*shi yu,* 'stone oil') ; the smoke emanating from it is very thick; the black produced by it can be made into ink. It has a black gloss like varnish, but cannot be employed medicinally."

The use of this petroleum ink inaugurated under the Sung has already been pointed out. It is also mentioned by Shön Kwa, who wrote the *Mong k'i pi t'an* in the middle of the eleventh century. He states that the natives of Yen-ngan in Shen-si burnt petroleum in their lamps, swept the lampblack together, and made it into ink, which had a deep black brilliancy like varnish, and which was superior to ink made from pine-resin.

There seems to have been some good reason for K'ou's cautioning against the medicinal employment of Korean ink; for it is on record that flies when sucking the juice of it would die, but by dint of what poison remained unknown. The same author alludes to the use of oak-galls as a hair-dye and ink for domestic purposes; but this is an isolated instance, and such ink has never become popular.

Under the art-loving emperor, Hui Tsung (1100-25), attempts were made to mix lampblack with storax, the sweet-scented resin of *Liquidambar orientalis* and *L. altingiana* (cf. *Sino-Iranica,* p. 456). It is said that an ounce of this ink was worth a pound of gold, and that efforts to imitate it failed.

Of oils of animal origin, preference was given to lard. On this point the Jesuit Louis Le Compte, at the end of the seventeenth century, writes that "China ink is not so difficult to make as people imagine; although the Chinese use lampblack drawn from divers matters, yet the best is made of hog's grease burnt in a lamp: they mix a sort of oil with it to make it sweeter, and pleasant odors to suppress the ill smell of the grease and oil. After having reduced it to a consistence, they make of the paste little lozenges, which they cast in a mould; it is at first very heavy, but when it is very hard, it is not so weighty by half, and that which they give for a pound, weighs not above eight or ten ounces."

Fan Ch'eng-ta, in his interesting work *Ling wai tai ta,* which deals with the geography and products of southern China, and which was written in A.D. 1178, has the following note on ink (Ch. 6, p. 2b): "In Jung-chou (prefecture of Wu-chou, Kwang-si Province) there is an abundance of large pine-trees from which the inhabitants manufacture ink. Good qualities are sold by the pound (catty) which is worth two hundred copper coins only.

The merchants raise the money jointly for the purpose and sell the stock as a whole. The ink of Kiao-chi (Tonking), although not very good, is not quite worthless either. The people barter their ink for horn, ink-slabs, and writing-brushes which they carry suspended from their loins."

John Francis Davis (*China,* Vol. II, 1857, p. 180) writes, "Chinese ink has been erroneously supposed to consist of the secretion of a species of sepia, or cuttle-fish. It is, however, all manufactured from lampblack and gluten," etc. Likewise J. Dyer Ball (*Things Chinese,* 4th ed., 1903, p. 105) asserts, "A curious idea was prevalent at one time in the west that the so-called Indian ink was prepared from the coloring matter of the cuttle-fish, instead of being made from lampblack as its principal ingredient." These statements are only partly true. The fact remains that the Chinese formerly made use of sepia also, though to a limited extent.

The cuttle-fish styled by the Chinese "*wu-tse* fish" was already known to T'ao Hung-king (A.D. 452-536), a celebrated physician and alchemist, who says that this creature carries ink in its belly, and that this substance was used as ink in his time. It is therefore called also "ink-fish" (*mo yü*). It is popularly believed to be a transformation of a crow, and another legend has it that it owes its existence to the emperor Ts'in Shi when he dropped his writing outfit into the sea. This cephalopod is met with all along the coast of China and forms an article of trade at Ning-po and Wen-chou in Che-kiang. Large quantities are eaten dried or pickled, or taken as a tonic. The small bag of inky fluid situated near the liver of the cuttle-fish is understood to be its gall. The preparation of sepia as a pigment, however, was never understood; and the employment of the secretion as ink has never attained popularity, as it fades within a few years.

Peter Mundy, who visited Canton and Macao in 1637, toward the end of the Ming dynasty, is one of the earliest European travellers who has recorded the use of ink in China. He noted that "they all write with pencills and blacke and red incke made into dry paste which they distemper with water when they will use it." He likewise gives a rough sketch showing a Chinese at his desk engaged in writing and an ink-well "which holds his incke, the one side containing blacke, the other redde; little partitiones with water where he dippes his pensill and so tempers his incke."

A formula for making ink from orpiment is given as follows: "Ochre should be pounded into a very fine powder over which water is swiftly poured to clarify it. The water is poured out. Take the bark of *ts'in-p'i* (*Fraxinus pubinervus*), fruit of Gardenia, and pods of *Gleditschia chinensis,* one-tenth of an ounce of each, one grain of the seeds of *Croton tiglium* after removal of the skin, mix this with a half ounce of bright yellow Kwang-tung glue made from ox-hides, boil this mass, mix it with the ochre and form it into cakes; or let it dry in the shade and use it thus."

I add two recipes from Du Halde's *Description of China* (1738) which he says "are taken from the Chinese, and which perhaps may suffice to make the ink of a good black, which is looked upon as an essential property. Burn, say they, lampblack in a crucible, and hold it over the fire till it has done smoking. In the same manner burn some horse-chestnuts, till there does not arise the least vapor of smoke. Dissolve some gum tragacanth; and when the water in which the gum is dissolved becomes of a proper consistence, add to it the lampblack and horse-chestnuts, and stir all together with a spatula. Then put this paste into moulds; and take care not to put in too much of the horse-chestnut, which would give it a violet black.

"A third receipt, much more simple, and easier to be put in practice, has been communicated to me by P. Contancin, who had it from a Chinese, as skilful in this matter as anyone can be expected to be; for we ought not to suppose that the ingenious workmen discover their secret; on the contrary, they take the greatest care to conceal it, and make a mystery of it, even to those of their own nation.

"They put five or six lighted wicks into a vessel full of oil, and lay upon this vessel an iron cover, made in the shape of a funnel, which must be set at a certain distance, so as to receive all the smoke. When it has received enough, they take it off, and with a goose feather gently brush the bottom, letting the soot fall upon a dry sheet of strong paper. It is this that makes their fine and shining ink. The best oil also gives a lustre to the black, and by consequence makes the ink more esteemed and dearer. The lampblack which is not fetched off with the feather, and which sticks very fast to the cover, is coarser, and they use it to make an ordinary sort of ink, after they have scraped it off into a dish.

"When they have, in this manner, taken off the lampblack, they beat it in a mortar, mixing with it musk, or some odoriferous water, with a thin size to unite the particles. The Chinese commonly make use of a size, which they call *niu kiao* ('size of neat's leather'). When this lampblack is come to the consistence of a sort of paste, they put it into moulds, which are made in the shape they design the sticks of ink to be. They stamp upon the ink, with a seal made for that purpose, the characters or figures they desire, in blue, red, or gold color, drying them in the sun, or in the wind."

An Arabic author, Abu'l Faraj (A.D. 988), writes that the Chinese have an ink composed of a mixture resembling

Chinese grease. He pretends to have seen specimens in the form of tablets representing the image of the emperor, and adds that a piece like this will last for a long time. This notice is of interest in that it shows that ink-cakes were embellished with designs at that early date; yet, the Arabic writer must have been mistaken as to the subject of the picture, for the emperor's portrait was never allowed to be turned to so profane a purpose, nor has it ever been customary in China to circulate an emperor's portrait during his lifetime. No imperial portrait appears on any Chinese coin, the only exception being in recent times that of the emperor Kuang-sü on the Tibetan rupee (coined in Ch'eng-tu for the purpose of counteracting the influence in Tibet of the Anglo-Indian rupee bearing the portrait of Queen Victoria).

In Chinese records we read of representations of dragons on inks of the T'ang and Sung periods, but the Ming dynasty (1368-1643) was the great era when ink manufacturers appealed to noted artists for designs and pictorial representations to be applied to their products. Many specimens of this art have survived, and are eagerly bought by Chinese collectors. Some ink manufacturers published books containing illustrations of all pictures placed on their inks. Two of these works are especially prominent. One is the *Fang shi mo p'u*, published in 1588 in six volumes by Fang Yü-lu, who manufactured ink at Shö hien, forming the prefectural city of Hui-chou in An-hui Province. Most of his illustrations were contributed by an eminent artist, Ting Yün-p'eng, who usually signs his pictures Nan-yü. He was a native of Hiu-ning in An-hui, and thus in close contact with his countryman, Fang Yü-lu. His designs are highly artistic, exceedingly fine, and well drawn, and represent a microcosm of Chinese mythology, as well as a thesaurus of art-motives.

Nan-yü revived several ink designs of which merely a literary reminiscence was preserved; thus an ancient text says that there formerly was an ink of nine children (*kiu tse mo*), which implied the wish that the owner of the ink may be blessed with an abundance of progeny.

Hence Nan-yü introduced the drawing of nine boys engaged in play, flying a kite, riding a hobby, manipulating a movable puppet, beating gongs and a drum. A goodly number of ink pieces are fashioned in the shape of archaic jade ornaments; others, in the shape of a peach-leaf, conch-shell, or bell; others are adorned with designs of palaces, terraces, landscapes, flower-pieces, birds and quadrupeds, the eight famous steeds of King Mu, star-gods and other deities of ancient lore, or Buddhist emblems accompanied by Indian scripts. This, of course, is not the place to give a detailed account of the variety and significance of these designs; suffice it to call attention to this artistic development of ink-cakes which is a unique phenomenon in the history of art.

The other work is the *Ch'eng shi mo yüan* in twelve volumes, issued by Ch'eng Kün-fang (or Ta-yo, but commonly called Kün-fang) between 1594 and 1606, an excellent copy of which, printed on Korean paper, was secured by the writer for the American Museum of New York in 1901, another for the John Crerar Library of Chicago in 1908. This belongs to the finest and most artistic examples of Chinese book-making. It contains 385 cuts accompanied by explanations, essays, and poetry, the handwritings of the authors being reproduced in facsimile. One of the interesting features of Ch'eng's work is that it contains four Christian pictures contributed by the celebrated Jesuit Matteo Ricci, who arrived at Macao in 1582, and who died in 1610; the engravings are accompanied by an essay and explanations written in

Chinese by Ricci himself and reproduced in facsimile. They have been published by the writer in an essay entitled "Christian Art in China."

The Newberry Library of Chicago received from the writer a similar Japanese book, entitled *Ko-bai-en boku-fu* [in Chinese: *Ku mei yüan mo p'u,* (*Collection of the Inks of the Old Plum-tree Garden*)], published in 1773, in five volumes. The first of these contains a number of prefaces, two volumes are filled with eulogies of ink facsimiled in the handwritings of the authors, and two others are occupied by engravings of ink designs. In the main, these follow the models of their Chinese prototypes, but do not quite display their vigor and power; yet, in some cases, they also exhibit original subjects, for instance, ink-cakes in the form of a daimio's suit of armor, bow, and boots. One bears the name of the illustrious Li T'ing-kwei of the T'ang; another is adorned with the picture of the Envoy of the Black Pine, the spirit or genius of ink who, according to a legend, appeared one day to the emperor Hüan Tsung of the T'ang dynasty.

Ink is a favorite gift among scholars and gentlemen, and for this purpose special boxes are made up in a very elegant and tasteful manner. In consideration of some courtesies which had been shown his son, a high Chinese official of Peking once presented the writer with a box containing eighteen ink-cakes, each adorned with the portrait of a famous scholar in low relief, his name being written in gold, the reverse of each cake bearing a stanza accompanied by seals in gold. Nine cakes are arranged in a finely lacquered tray, the inside of which is mounted with yellow silk. Each tray has its separate cover likewise lacquered black, decorated with a border design in gold, and inscribed with four large characters in heavy gold (*fang ku tsang yen,* "in imitation of ancient lampblack"). The two lacquer boxes fit into a card-board case mounted on decorated cloth in the style of bookbindings, and the whole presents the appearance of a book. Other such series are exquisitely adorned with celebrated landscapes or mountain scenery, or show all the stages in the process of tillage and weaving.

For preserving ink, wrapping it up in a leopard-skin is recommended by Fung Chi in his *Yün sien tsa ki* (Ch. 1, p. 7), written in the beginning of the tenth century. The remedy may be efficient, but leopard-skins were not within everyone's reach, nor hardly ever available in a quantity sufficient to go round. The average man therefore had to be content with a plain box in which mugwort (*Artemisia vulgaris*) was placed as a means of preserving the ink. The main point is that it should not be exposed to sunlight which would cause it to crack and crumble to pieces. The box therefore must be tight-fitting. As early as the T'ang period special boxes were turned out for keeping ink, and great luxury was displayed in them under the Sung and Ming. They were made of a kind of sandalwood (*Pterocarpus santalinus*), ebony, or nan-mu (*Persea nanmu*), a valuable timber of Se-ch'wan, which does not easily rot, and which for this reason is much used for buildings and furniture. The wood was inlaid with jade plaques derived from the court-girdles of the T'ang period or with designs of hydras, tigers, and genre-scenes carved in jade; it was also coated with red and black lacquer.

The prominent qualities of Chinese ink are well known. It produces, first of all, a deep and true black; and second, it is permanent, unchangeable in color, and almost indestructible. Chinese written documents may be soaked in water for several weeks without washing out. It is safely used to mark linen. In documents written as far back as the Han period in the beginning of our era, and discovered under the sand of Turkestan, the ink is as bright and well preserved as though it had been applied but yesterday. The same holds good of the productions of the printer's art. Books of the Sung, Yüan, and Ming dynasties have come down to us with paper and type in a perfect state of preservation. Above all, we owe to the perfect ink of the Chinese many masterpieces of the brush in black and white and that charming art of monochrome drawing. Li Kung-lin or, as he is better known, Li Lung-mien, was one of the greatest masters of the line who ever lived, and the inspirations of his genius were merely expressed by black ink on white paper; he made the ink live and speak, drawing his lines in hundreds of shades.

Speaking of the qualities of China ink, the Jesuit Louis Le Compte (Memoirs and Observations made in a Late Journey through the Empire of China, p. 192, London, 1697) wrote at the end of the seventeenth century, "This ink is shining, extreme black, and although it sinks when the paper is so fine, yet does it never extend further than the pencil, so that the letters are exactly terminated, how gross soever the strokes be. It has moreover another quality, that makes it admirable good for designing, that is, it admits of all the diminutions one can give it; and there are many things that cannot be represented to the life without using this color."

Naturally Europe endeavored to rival the Chinese competition. Attempts were made in France at an early date to imitate China ink. Father Le Compte writes with reference to this subject, "It is most excellent, and they have hitherto vainly tried in France to imitate it; that of Nanking is most set by: And there are sticks made of it so very curious and of such a sweet scent that one would be tempted to keep some of them though they should be of no use at all." Likewise Du Halde, in his *Description of China* (London, 1738) observes, "The Europeans have endeavored to counterfeit this ink, but without success. Painters and those who delight in drawing know how useful it is for tracing their sketches, because they can give it what degree of shade they please." And still in 1869 P. Champion (*Industries anciennes et modernes de l'empire chinois,* p. 129) wrote that many attempts were made in France to manufacture Chinese ink, but that the results have never been entirely satisfactory, and that the ink of Chinese origin, superior in quality to the French products, has always been preferred by the draughtsmen. Chinese ink can be made only in China, and will never be equalled anywhere else.

Hui-chou in An-hui Province, where ink manufacture was so successfully initiated under the T'ang, is the high seat of the industry also at the present day. It is still of interest to read Du Halde's account of the Hui-chou factories.

"We are assured," he writes, "that in the city of Hui-chou, where the ink is made which is most esteemed, the merchants have great numbers of little rooms, where they keep lighted lamps all day; and that every room is distinguished by the oil which is burnt in it, and consequently by the ink which is made therein. Nevertheless many of the Chinese believed, that the lampblack, which is gathered from the lamps in which they burn oil of gergelin (sesame), is only used in making a particular sort of ink, which bears a great price, but considering the surprising quantities vended at a cheap rate, they must use combustible materials that are more common, and cheaper.

"They say that lampblack is extracted immediately from old pines, and that in the district of Hui-chou where the best ink is made, they have furnaces of a particular structure to burn these pines, and to convey the smoke through long funnels into little cells shut up close, the insides of which are hung with paper. The smoke being conveyed into these cells, sticks to every part of the wall and ceiling, and there condenses itself. After a certain time they open the door, and take off a great quantity of lampblack. At the same time that the smoke of these pines spreads itself in the cells, the resin which comes out of them runs through other pipes, which are laid even with the floor.

"It is certain that the good ink, for which there is a great demand at Nanking comes from the district of Hui-chou, and that none, made elsewhere, is to be compared with it. Perhaps the inhabitants of this district are masters of a secret, which it is hard to get out of them. Perhaps also the soil and mountains of Hui-chou furnish materials more proper for making good lampblack than any other place. There is a great number of pine-trees; and in some parts of China, these trees afford a resin much more pure, and in greater plenty, than our pines in Europe. At Peking may be seen some pieces of pine-wood which came from Tartary, and which have been used for above these sixty years. Nevertheless, in hot weather, they shed a great quantity of big drops of resin, resembling yellow amber. The nature of the wood which is burnt contributes very much to the goodness of the ink. The lampblack which is got from the furnace of glass-houses, and which the painters use, may perhaps be the properest for imitating Chinese ink.

"As the smell of the lampblack would be very disagreeable, if they were to save the expense of musk, which they most commonly mix with it; so by burning such drugs, they perfume the little cells, and the odors mixing with the soot, which hangs on the walls like moss, and in little flakes, the ink they make thereof has no ill scent."

Hui-ning in the prefecture of Hui-chou is now the centre of the ink industry of An-hui Province. From there the whole of China is supplied with ink. That of the family Hu K'ai-wen enjoys a special reputation. It sells its product from 300 copper coins up to 48 ounces of silver (taels) for the pound which includes 30-32 cakes of medium size. The ink of the first class is made by varnish and sesame oil; that of the second class, by sesame oil and lard; that of the third class, by the oil of colza; and that of the fourth class by t'ung oil. Each of these substances makes inks of very different quality, according to the number of lamps and the degree of slowness of combustion. Two good workmen can turn out eighty pieces daily, each half a pound in weight (cf. H. Havret, La Province du Ngan-hoei, p. 38).

In 1863, according to S. Wells Williams' *Chinese Commercial Guide,* the finest ink was priced as high as Mexican $5 a catty (about 1⅓ lbs.), common sorts ranging from $0.40 to $1.50. The boxes destined for export to Europe usually contained a hundred cakes.

The usual method of printing books in China and Tibet is that by means of wooden blocks. For this purpose, the manuscript is first written on thin paper by a professional caligraphist. This paper is pasted over the finely planed block with the characters turned face downward, the thinness of the paper displaying the writing perfectly through the back. Then commences the engraver's work, who chisels down the surface of the block around the characters, so that the writing in negative stands out in relief. In this state, the blocks go to the printer, who lightly rubs ink over them with a round brush of coir-palm fibre, places a sheet of paper on them, and takes the impression by passing another brush over.

In regard to printer's ink, old Du Halde (1738) has supplied the following information from the reports of the Jesuits:—

"The ink which they use for printing is a liquid, and therefore much more convenient than that which is sold in sticks. To make it, you must take lampblack, pound it well, expose it to the sun, and then sift it through a sieve. The finer it is, the better. It must be tempered with Aqua-vitæ till it comes to the consistence of size, or of a thick paste, care being taken that the lampblack may not clot. After this it must be mixed with a proper quantity of water, so that it may be neither too thick, nor too thin. Lastly, to hinder it from sticking to the fingers, they add a little neat's leather glue, probably of that sort which the joiners use. This they dissolve over the fire, and then pour on every ten ounces of ink almost an ounce of glue, which they mix well with the lampblack and Aqua-vitæ, before the water is added to them."

De Guignes (*Voyages à Peking* 1784-1801, Vol. II, p. 229) gives the following note on printer's ink: "For purposes of printing they avail themselves of a particular and rather fluid ink. It is made from lampblack finely ground, which is passed through a very fine sieve. It is then soaked in rice wine, and when it has the consistency of a pap, glue is added at the dose of an ounce for ten ounces of lampblack. The whole is mixed together, with the addition of the necessary quantity of water."

For printing-ink, S. Wells Williams informs us, the lampblack is mixed with strained congee or a vegetable oil; and when the paste is properly dried, it is kneaded on a slab and cut into strips shaped like wrought nails. The printers grind it, or dilute it in oil as they use it, laying it on the wooden blocks with a brush made from the bark of the coir-palm.

At the present time large quantities of printer's ink are imported into China from Japan, and that of Japan is made according to European methods.

A specimen of powdered printer's ink obtained by the writer in 1910 from a Tibetan monastery, but presumably of Chinese origin, was examined by Henry W. Nichols, associate curator of geology in the Field Museum, Chicago. It was actually used with good success in the Museum's printing office. Mr. Nichols reports as follows:—

"I have made a qualitative chemical examination of the Tibetan ink powder submitted. The material is a nearly black powder of medium coarseness. A sizing test shows 30% retained on a twenty mesh sieve and only 10% fine enough to pass a hundred mesh sieve. The powder is evidently to be reground before used for ink. Under the microscope some of the larger particles take the form of broken fragments, others show spherical and botryoidal surfaces covered with small projecting points. Still others have a rough cellular appearance like that of clinkers and cinders from a coal fire. There is no trace of organic structure apparent.

"The ink is composed principally of carbon. When it is burned, the ash is too great in quantity for charcoal and too little for bone or ivory black. The ash is principally phosphate of calcium with smaller quantities of iron, alumina, silica, and undetermined elements. The ink cannot be a soot like lampblack or carbon black on account of the coarseness. The quantity and character of the ash show that it cannot be a pure charcoal nor a pure bone black.

"The examination indicates that this ink is similar to the older form of drop black except that the process of manufacture has been carried one step further than is the case with bone black. Charred ivory, teeth or the denser parts of bone has been mixed with charcoal and finely ground. The powder has been cemented into a cake with glue, gum or some similar substance. The cake thus formed has been ground to a coarse powder which has been recharred. Heath and Milligan described the old style of drop black thus: Drop Black, as the name implies, was first placed on the market in the form of small lumps or drops and consisted of various mixtures of animal and vegetable blacks ground to a fine powder with water, mixed with a little gum and then moulded into drops and dried. The Chinese material differs from this in that the moulded drops or cakes have been powdered and reburned. The object of adding bone black to the charcoal is to improve the color."

As any substance found in nature and any artifact, ink also has invaded the materia medica of the Chinese. In the *Pen ts'ao kang mu,* written at the end of the sixteenth century and regarded as the standard herbal of the late Ming and Manchu periods, ink is described as astringent, diuretic, emmenagogue and vulnerary in its qualities. It is recommended as an application to the eye when irritated by the presence of foreign bodies. Not so long ago, and perhaps still at present, stale ink was administered as a kind of paint for daubing over tumors and swellings of all kinds, also for treating ulcers and wounds. This does not appear so bizarre if we remember that similar practices prevailed among us. Thus Francesco Carletti (*Ragionamenti sopra le cose da lui vedute ne' suoi viaggi,* Vol. I, p. 84), who visited Peru in 1595, relates that the wound caused by an injurious insect called *higna* when removed from the skin was healed by the application of a little ink.

Du Halde writes, "When the ink has been preserved a long time, it is then never used for writing, but becomes, according to the Chinese, an excellent and refreshing remedy, good in the bloody flux, and in the convulsions of children. They pretend, that by its alkali, which naturally absorbs acid humors, it sweetens the acrimony of the blood. The dose, for grown persons, is two drachms, in a draught of water or wine."

At the end of the eighteenth century de Guignes even recommended old Chinese ink for hemorrhages and the stomach, provided that it is of superior quality. This effect, he comments, is not surprising, as it is combined with *ngo-kiao* or glue from asses' skins, which is a supreme remedy in blood-vomiting. According to de Guignes' description asses' glue would enter the composition of every ink, which, of course, is not true.

Writing-brush and ink have become so essential requisites and attributes of scholarship that *pi mo* ("brush and ink") has developed into a term denoting literature. The phrase "he talks of nothing but pen and ink" means that his hobby is literature. "Eating ink" is a common phrase for studying, from the habit of the Chinese of putting the writing-brush into the mouth in order to give it a fine point. The question addressed to a scholar, "how many years' ink have you eaten?" means as much as "how long have you been studying?" A skilled writer is said "to scatter ink and make pearls."

Under the first emperor of the Liang dynasty (A.D. 502-556) candidates who failed in the examinations for the degree of *siu-ts'ai* were made to drink long draughts of liquid ink.

Ink has naturally entered into proverbial sayings also. "It is not the man who rubs (wears out) the ink, it is the ink which wears out the man,"—by his application to study. "He who is near ink gets black; he who goes near vermilion will make himself red." Written notes are regarded as preferable to memorizing. This is expressed by a proverb which says, "The palest ink is better than a capacious memory"; also quoted in the form, "A clever memory is not equal to a clumsy brush."

Poetical names for ink are "black metal," "dark incense," "black-jade ring."

The Chinese never keep liquid ink in bottles or ink-wells, but prepare only as much as they actually need at a time. For this purpose they avail themselves of a slab of marble or other stone which has a small rounded cavity at one end. A few drops of water are poured over the finely polished surface, and the stick or cake of ink is gently rubbed against it, the ink flowing into the cavity. Many ink-sticks are provided with a rounded notch at the lower end to secure a firmer hold for the finger, while the upper part to be rubbed is rounded; in this manner one avoids confounding the two ends, as the wetted portion will naturally leave black spots on the fingers. The marble, before being used, must be carefully washed, so that no trace of old ink remains upon it; for even a small particle of old ink adhering to it is said to spoil both the marble and the fresh ink. The marble should not be cleaned with hot water or cold water just drawn from a well, but with water that has been boiled, and has grown cool again. The selection of the proper materials for ink-pallets and their preparation and carving has developed into a science in itself, and this subject has called forth a literature as exuberant as that on ink.

White jade makes the finest ink-stones, and there is a specimen in the Field Museum in the form of a well-frame, where the cavity is suggestive of a well,—a veritable ink-well. Another very ancient specimen of cast iron is provided with a lower compartment for heating water with charcoal. A peculiar fad came into vogue during the eighteenth century to convert the ancient roofing-tiles from the palaces of the Han emperors into ink-pallets. The Field Museum has a very fine stone ink-slab of the T'ang period with carved figures of a lion and lioness of realistic style. The Twan-k'i stone has been famed from remote times for its use as ink-pallets; Twan-k'i is an old name for Te-k'ing, a district in the prefecture of Chao-k'ing in Kwang-tung Province, where the quarries are situated. Several monographs have been written on this stone alone.

Glancing back at the preceding sketch which gives a mere outline of the history of ink in China, we recognize a constant ascending development, a gradual improvement and perfection of methods finally culminating in the best and most durable ink produced in the world. In principle, the composition of all Chinese inks is identical: the fundamental substance making the ink is lampblack from whatever source it may be derived; this is compounded with glutinous matter, the glue serving the purpose of uniting the fine particles of carbon and fixing the ink on paper by means of the brush. The perfumes sometimes added, like musk, camphor or patchouly, have the function of hiding the unpleasant odor of the glue, but are unessential. The numerous different varieties and grades of ink depend upon the fineness and quality of the lampblack, the quality of the glue, the proper proportions of the two, the process adopted in mixing them, and general methods of manufacture usually kept very secret. Another differentiation comes in from the addition of accessory vegetable, mineral, or chemical substances, which seem to vary in the hands of every manufacturer. For these reasons it is obvious also that an absolutely correct description of the process which would hold good or be typical of all factories cannot be given. Few foreigners had occasion to obtain access to them, and still fewer possessed the technical knowledge to describe exactly what was going on.

A French chemist, Paul Champion, has studied the process at Shanghai and Hankow toward the middle of the nineteenth century, and has given a brief description of it (*Industries anciennes et modernes de l'empire chinois,* p. 136, Paris, 1869).

CHAPTER III

THE HISTORY OF INK IN JAPAN

ACCORDING to the Nihongi (*Annals of Japan*), the king of Korea sent in A.D. 610 two Buddhist priests to Japan, one of whom, the Korean priest Tan-cheng or Tam-ch'i from Kao-li, was skilled in preparing painters' pigments, paper, and ink. He introduced into Japan the technique of manufacturing ink and paper. This industry was ardently advocated and promoted by the celebrated Japanese prince, Shotoku Daishi (A.D. 572-621), the propagator of Buddhism in Japan.

In the beginning the Japanese availed themselves only of the black derived from resinous woods like pine-tree (Japanese *sho-yen* or *matsu no kemuri*). At a later date, however, they learned from the Chinese the method of making a superior ink from the black of oil-lamps (Japanese *yu-yen* or *abura-susu*), and this process has now superseded the pine-soot method. Although Japan itself manufactures the greater part of the ink (*sumi*) required by the country, the Chinese product is looked upon as superior in quality and commands a higher price.

In principle, the process of manufacture is identical with that of China, but deviates somewhat in details. The lamps used for the purpose are small crucibles or dishes of stoneware, with wicks of rush-pitch. A cone-shaped soot catcher or reversed bowl of burnt clay, but unglazed, is placed over each lamp and is replaced with a new one every hour. The rough clay is preferred so that the black matter precipitates in the porous surface. When exposed to the flame too long, it would become too compact. The soot is carefully brushed off and swept together, and is then sifted through a fine hair-sieve. The glue to be added to this substance is made from ox-hides and isinglass, and must be very bright, acting as it does as a cement. To ten catties (13⅓ lbs.) of lampblack from the oil of *Aleurites vernicia,* four catties of old ox-hide glue and one-half catty of old isinglass are reckoned; oil of sesame and colza also are utilized.

These ingredients, after the glue has been boiled in the necessary amount of water, are thoroughly mixed in a porcelain dish or copper basin,—a toilsome process, as the lampblack does not readily combine with water. This being done, the mass may be kneaded and pressed like dough, and is shaped into round balls which are wrapped in cloth. They are placed in a stoneware jar with perforated bottom to be subjected to steam for fifteen minutes. The material is then taken out and wrought with a pestle in a mortar for at least four hours, until it is thoroughly homogeneous and plastic. It is, further, fashioned into large prismatic bars which for a moment are exposed to a temperature of about 50° Celsius in a jar, and then stretched into longer sticks. These are beaten with mallets on an anvil and constantly turned till they have acquired not only the proper form, but also the desired lustre. They are once more kneaded on a smooth table; musk, camphor, or some other odoriferous substance being added, and then shaped by hand and put in a wooden press.

Ashes from rice-straw, carefully sifted and dried in the sun, are used for drying the sticks. For this purpose a layer of ashes about an inch thick is placed in the drying-box to be followed by a layer of ink-sticks; then ashes again, and another layer of sticks covered by ashes on the top. The length of the drying process depends on the quantity of water contained in the ink. When satisfactorily dry, the sticks are removed from the ashes, brushed off, laid in a small sieve, and for a day or two are left in a shady spot, where the drying process is completed. They are then polished by means of a brush, sometimes varnished and gilded, and any required legends as manufacturer's name, name of place, devices or mottoes are impressed on the surface.

This ink should not be used for several years after making, as hardness, blackness, and lustre increase with age. The same rule is observed in China. The quality depends largely on the fineness and lightness of the lampblack, the purity of the glue, and carefulness observed during the several stages of manufacture. Sound and a tinge of brown color are regarded as criteria by which to recognize and judge the best pieces. Ink of the first quality is uniform, without cracks or blemish, and brilliant in its fracture. In rubbing it with water on the inkstone it must not crackle; that is, it must be entirely free from any kind of sandy matter. The odor is required to be that of a pleasing blend of musk and patchouly; the color, that of a black-brownish with a slightly russet tint. The writing when dry must have frigid and glossy tones. The sticks of prime quality, as a rule, have a plain surface without much decoration, and are completely gilded; while those of secondary or inferior quality are usually more highly ornate.

Musa from the province of Omi, Kaibara from the province of Tamba, and Taihei from the province of Yamashiro formerly were renowned brands of ink. At the present time it is the city of Nara, the ancient capital of Japan situated between Kyoto and Osaka, and the manufacturers Matsuda and Matsumura in the province of Kaga who enjoy the greatest reputation for their output of ink.

The pallets for rubbing the ink on (Japanese *sudzuri*) are made in imitation of Chinese and Korean models, usually of a fine-grained dark stone, chiefly old slate, serpentine, or colored marble. In Japan an old, dark blue slate is especially prized for this purpose, and is generally used. It is found in the neighborhood of Amabata, a small town in the province of Kiushiu, and is hence known throughout the country as "stone of Amabata" (*Amabata-ishi*). A cavity is inserted on one side of the stone to serve as a receptacle for water. When ink is required, a few drops of water are poured into the hollow, the stick is dipped in, the water being brought up by it to the surface of the pallet. The ink-cake is rubbed against the stone, and the ink gradually flows back into the well, ready for use.

The Japanese business man always carries with him a portable writing-case (*yatate*), including a holder for fluid ink and a writing-brush enclosed in a metal case. For household purposes is furnished a box with several compartments (*sumi-ire*),—one for brushes, another for ink-cakes, and a third for the ink-stone.

The illustration of a Japanese writing-desk may be seen in Edward S. Morse's *Japanese Homes and Their Surroundings* (p. 317). The usual form consists of a low stool not over a foot in height, with plain legs for support, sometimes having shallow drawers. This is about the only piece of furniture in a Japanese house that would parallel the style of writing-table used in the western part of the world. Paper, paper-weight, ink-stone with ink, water-bottle, brushes, and brush-rest are placed on the desk in the same manner as in China. On page 141 of the same work Morse gives a sketch illustrating the writing-place in a guest room.

PRINTING INK

In preparing ink for wood-block printing, ink-cakes are macerated in water for a few days, until the glue contained in it is dissolved and the mass becomes sufficiently softened. It is then ground by means of pestle and mortar. After it has been mixed with water, glue solution or rice paste, according to the printer's judgment, has to be added. If glue solution is employed, it should be mixed with the lampblack in a basin; but rice paste is mixed with the pigment on the plank by means of the brush.

CHAPTER IV

THE HISTORY OF INK IN CENTRAL ASIA

OWING to the geographical position of the country, the culture of Tibet is of a dualistic character in its absorption of foreign ideas: on the one hand these have filtered in along its southern border from India, and on the other hand along its eastern frontier from China. While the alphabet, literature, and religion were received from India, all practical industries came from China, and so it was with paper and ink.

Under the first powerful Tibetan king, Srong-btsan sgam-po, who died in A.D. 650, writing was introduced from northern India, and soon afterwards the king invited scholars from China to draft his official reports to the emperor whose daughter he had received in marriage in A.D. 641. In 648 he applied to his imperial father-in-law for workmen capable of manufacturing paper and ink, and this request was granted. From this date onward the Tibetans joined the ranks of literary nations, and in a few centuries developed a literature of an astounding extent. They likewise adopted from the Chinese the art of block-printing, and we now have at our disposal Tibetan writings as early as the ninth century. It follows from the preceding account that the Tibetans learned the preparation of ink from the Chinese; but the bulk of their ink is still imported from China.

Colored inks, and especially writing in gold and silver, are mentioned in Tibetan literature at an early date. Copying a religious book means accumulation of religious merit, and the merit is graded in accordance with the color of the ink: gold is regarded as first in rank; silver, as second; vermilion, as third; and black, as fourth. Gold and silver manuscripts are written on a stiff, heavy paper of black glossy background surrounded by a blue border.

As early as the beginning of the fourteenth century the first copies of the Buddhist canon, known as the Kanjur and Tanjur (making about 230-245 large volumes), were produced in gold writing by Sa-skya Pandita, and subsequently we hear of a number of such editions of the sacred scriptures both in gold and silver, also in an alloy of both of these metals. A superb edition of the Kanjur in vermilion was issued in 1700 from the press of the imperial palace of Peking (so-called palace edition) by order of the emperor K'ang-hi, and another of the same character by his successor, K'ien-lung.

In China and Japan also Buddhistic manuscripts in gold are occasionally found; hence we may infer that this practice was propagated by the Buddhist clergy. In the West gold-writing reached its highest development among the Byzantines (cf. V. Gardthausen, *Buchwesen im Altertum,* p. 214).

The Tibetans do not rub ink on a stone, as the Chinese do, but carry it dissolved in brass ink-pots, together with a pen-case, which are suspended from the girdle. The pens are bamboo styles placed in pen cases of brass, copper, silver, or iron inlaid with silver. In the collections of Field Museum, Chicago, writing materials from Tibet, including ink, pens, specimens of paper, manuscripts and prints, and all implements used in printing, are on exhibition.

In Tibet as well as Mongolia, the pupils in the schools use as slates slabs of black painted wood, dusted over with white chalk, on the surface of which the writing is done with a style.

The Lolo, an aboriginal tribe inhabiting parts of Se-ch'wan and Yün-nan and distant kinsmen of the Chinese and Tibetans, manufacture ink from a soft schist of blood color, which is dissolved in water, and also from the ashes of a large mushroom that grows on the trunk of an oak. They use a style of a tender wood for writing, and at the present time avail themselves of Chinese paper. In ancient times they employed tree-bark for this purpose. In the collections of Field Museum are two Lolo documents written on oblong slips of wood.

In the *Mo shi* of Lu Yu, referred to above (p. 19), there is a brief notice of ink in Chinese Turkestan. A Buddhist monk named Su T'ai-kien is quoted as saying that in Turkestan there are neither ink-slabs nor writing-brushes (a wooden style was in use there), but only excellent ink which is not surpassed by that of China. It was prepared from old pine-trees growing in the Ki-tsu ("Chicken-foot") Mountains. T'ai-kien would keep leaves of the palmyra-palm inscribed with several hundred Sanskrit letters, the ink being twice as glossy as that of China. When at the time of the autumn rains the windows covered with such paper were wetted, the writing even though rubbed could not be wiped out.

Speaking of the documents inscribed on leather and discovered by him in Turkestan, Sir Aurel Stein (*Ancient Khotan,* Vol. I, p. 347) observes, "Owing to its exposed position on the outside surface, the writing of the address has often become faint or been partly rubbed off. But the ink on the obverse has in most cases retained remarkably well its original black color, and makes the writing clearly legible even in those cases where the leather itself has become discolored or stained. I regret not to have found an opportunity for arranging for a chemical examination of this ancient ink. But, judging from its appearance, it seems probable that it was Chinese (or Indian) ink, such as that of which a small stick was actually found by me among the rubbish layer inside the Endere Fort. The ink used on the tablets, both Kharoshthi and Chinese, varies considerably in quality and thickness, but I did not observe any indication pointing to a difference in the composition of the ink."

The Mongols appear to have borrowed their ink from China at a comparatively early date, as is proved by their word *bäkhä,* which is based on Old Chinese *mak, bak,* or *bäk.* The Manchu adopted the same word, presumably from the Mongols. In this connection it is interesting to note also that Mongol *sir* ("varnish") is borrowed from Old Chinese *tsit* or *tsir,* and Mongol *bir* ("writing-brush") from Old Chinese *bir, bit.*

In 1848 the great Finnish linguist, A. Castrén, wrote from Kiachta, "In the art of printing, the Mongol Lamas are comparatively less skilled than in writing; but it is curious enough that this very art is practised in this barbarous country. The Lamas, in accordance with their regulations, are obliged to know how to cut printing-blocks, to prepare printer's ink, and to print from the blocks."

CHAPTER V

THE HISTORY OF INK IN INDIA

IN considering the history of writing materials in India we are at the outset confronted with a psychological situation radically distinct from that in China and even almost the opposite to it. In China the written word and everything connected therewith were regarded with fervent reverence and treated as a fetish. Among the Brahmans of ancient India, it was not the written, but the spoken word which was looked upon as a fetish. The hymns of the Veda were memorized and transmitted for ages from generation to generation merely by memory; even at a time when an alphabet was in existence, the Brahmans first steadfastly refused to commit their sacred texts to writing, and but slowly and reluctantly yielded to this far-reaching innovation which threatened to break down the prerogatives of their caste. China never labored under a caste system; China has always been democratic, and placed the means of learning and education in the hands of whoever endeavored to learn and to read.

In India learning was the privilege of an exclusive sacerdotal class which kept in splendid isolation. In the Mahabharata it is said that those who sell, forge, and write the Veda are condemned to hell. In a society where such an aversion to writing prevailed it is not likely that much interest was evinced in the production and perfection of writing materials. It is striking also that despite her close contact with China, which set in from the first century A.D., India did not adopt paper and printing. Paper was introduced only in the Mohammedan period by the Arabs (there is no Sanskrit word to designate paper), and the first printing press in India was set up by the Portuguese at Goa in the sixteenth century. Whatever progress was made in India in the direction of writing must have been due to the caste of nobles and warriors, the Kshatriya, and to the merchants.

In the sixth century B.C. there were schools for methodically teaching the art of writing. Wooden writing-boards (*phalaka*) were in use, but these were incised with a stylus. The whole terminology relating to script and scribes hints at the fact that the letters were scratched in hard objects. There is no vestige of the use of ink in the early period. In the fourth century B.C. we learn from the Greek writers that prepared cotton-stuffs and birch-bark were employed in India, like papyrus, for writing letters. From this fact G. Bühler (*Indische Palæographie*, p. 91) is inclined to infer that ink was presumably used, and he confirms his supposition by palæographic evidence.

From the second century B.C. we have the oldest extant specimen of ink-writing on a stone vessel recovered from the tope (stupa) of Andher. In post-Christian times we have manuscripts written on birch-bark, the oldest being the small leaves folded and fastened with yarn (so-called "twists") discovered by Masson in the stupas of Afghanistan, followed by the famous Bower Manuscript which goes back to the fourth century A.D. Hoernle, in his edition and translation of the Bower Manuscript, says nothing concerning the ink. Aside from birch-bark, the leaves of several species of palm were enlisted as writing material in early times. Hüan Tsang, the famed Chinese Buddhist pilgrim, who visited India in 629-645, states that the leaves of the *tala* palm, which are long and broad and bright in color, are everywhere used for writing on in all countries of India.

In the Horiuji Monastery of Japan is preserved a Buddhistic palm-leaf manuscript inscribed with ink, and numerous such manuscripts of the ninth and later centuries from Nepal, Bengal, Rajputana, Gujarat, and the northern Dekhan demonstrate that in northern, eastern, central, and western India ink was used in writing upon palm-leaves. In Orissa and Dravidian India, however, the letters are incised in the leaf with a metal style, and are subsequently blackened with soot or charcoal. The use of palm-leaves for manuscripts is still common in southern India; the oldest manuscript extant there comes down from A.D. 1428. Palm-leaves were also used in southern India for letters, as well as official and private documents, and are still so used; there, and in Bengal likewise, they serve for writing in school. In the schools of Bengal banana-leaves also are said to be used and inscribed with lampblack ink.

In the Vasavadatta, a Sanskrit romance written by Subandhu in the seventh century A.D. and translated into English by L. H. Gray, occurs the passage, "The pain that has been felt by this maiden for thy sake might be written or told in some wise or in some way in many thousands of ages if the sky became palm-leaves, the sea an ink-well (*melamanda*), the scribe Brahma, and the narrator the Lord of Serpents."

John Fryer, who travelled in India and Persia for nine years (1672-81), informs us that the Persians "use Indian ink, being a middling sort betwixt our common ink and that made use of in printing: instead of a pen they make use of a reed, as in India."

We have a well-authenticated testimony for the existence of ink in India in the first century of our era in the

Periplus of the Erythrean Sea, a Greek work from the hand of an unknown author, probably written between A.D. 80-89, roughly about A.D. 85. In chapter 39 of this book *Indikon melan* ("Indian black") is given as one of the articles exported from the Indian port Barbarikon. The earlier commentators have explained this term as indigo, and B. Fabricius (in his edition of the *Periplus*, p. 152) is even inclined to interpret it as textiles made in India and dyed black. These opinions are not to the point, for the indigo of India is called in Greek simply *indikon*, in Latin *indicum* (cf., further, *Sino-Iranica*, pp. 370-371), while *melan* is the common Greek designation for ink: *Indikon melan*, consequently, means "India ink." Moreover, Pliny (*Hist. nat.*, XXXV, 25), in his chapter on ink (*atramentum*), points out "indicum, a substance imported from India, the composition of which is at present unknown to me," and says expressly that good ink prepared from dried wine-lees will bear comparison with that of indicum. Indigo is discussed by Pliny in a separate chapter.

There is hence no doubt that indicum signifies "ink of India," which was exported from India into the Roman Empire, and as confirmed by the Periplus, shipped together with other Indian goods from Barbarikon. Old Beckmann (*Geschichte der Erfindungen*, Vol. IV, 1799, pp. 489-496; cf. also Blümner, *Technologie*, Vol. IV, p. 517) has devoted a profound and ingenious investigation to the whole question, and has arrived at the same result. He thinks it very probable that the "Indian black" of the ancients was nothing but what is now termed India ink which approaches the finest ivory-black and lees-black so closely that by this means some still imitate it and actually delude ignorant buyers. "Ink in India," he concludes, "is in general use, and has presumably been so from earliest times; for in India almost all products of art are extremely ancient, but I do not mean to say that ink is a new Indian invention; it may have been improved, above all, by the Chinese."

There is no evidence to the effect that the Indian ink of the ancients was Chinese ink. In the first century A.D., as we have seen, it was still in its initial stages and very far from the perfection of the later days. All that we are permitted to assert safely is that the Indian ink of the ancients was an ink manufactured in India.

Blümner argues that the manufacture of Chinese ink is exceedingly old, and that in the same manner as Chinese silk was traded to the West, also ink might have arrived in Europe by way of India. Its native country being unknown, it was designated as Indian. There is, however, not a trace of documentary evidence for such a trade in ink, either in Chinese or in Western sources; and Blümner also adds cautiously that Chinese ink has not yet been traced in any paintings or pigments of classical antiquity; all investigations of black pigments have only yielded substances consisting of pure carbon.

The oldest Sanskrit designation for ink is *masi* or *mashi*. The word is indigenous, and according to Bühler, originally means "something ground, powder." It then came to denote several kinds of powdered charcoal which was mixed with gum-arabic, water, and sugar, and thus served as an ink. Another name for ink, *mela*, has been derived by some scholars from Greek *mélas* ("black"), but Bühler rejects this view and connects the word with Prakrit *maila* ("dirty, black"). According to L. D. Barnett (*Antiquities of India*, p. 231), ink was made in early times of charcoal mixed with water, sugar, gum-arabic, etc., and was applied with pens of wood or reed. A solution of chalk was also used as writing fluid, and was conveyed to the tablet by a wooden style.

In modern times the ink used for writing on paper is compounded of lampblack with an infusion of roasted rice, with the addition of a little sugar and sometimes the juice of a plant called *kesurte* (*Verbesina scandens*). It requires several days' continued trituration in a mortar before the lampblack can be thoroughly mixed with the rice infusion, and want of sufficient trituration causes the lampblack to settle down in a paste, leaving the infusion on top unfit for writing. Occasionally, acacia gum is added to give a gloss to the ink; but this practice is not common, sugar being held sufficient for the purpose. Of late, an infusion of the emblic myrobalan, prepared in an iron pot, has occasionally been added to the compound; but the tannate and gallate of iron formed in the course of preparing this infusion are injurious to the texture of paper, and Persian manuscripts sometimes written with such ink suffer much from the chemical action of the metallic salts.

The ink for palm-leaf consists of the juice of *Verbesina scandens* and a decoction of *alta* (cotton impregnated with lac dye). It is highly esteemed, as it sinks into the substance of the leaf and cannot be washed off. Both these inks are very lasting, and being perfectly free from mineral substances and strong acids, do not in any way injure the paper or leaf. They never fade and retain their gloss for centuries (after A. E. Gough, *Papers rel. to the Collection and Preservation of the Records of Ancient Sanskrit Literature in India*, p. 18, Calcutta, 1878).

Colored inks with which especially the Jaina produced beautiful manuscripts are frequently mentioned in Brahmanic literature, e.g., in the Puranas when donations of manuscripts are mentioned. Chalk and minium served as substitutes for ink in ancient times.

According to G. Watt's *Dictionary of the Economic Products of India,* at present various substances are used by the natives of India in making ink, the usual process being to mix some astringent principle such as galls or myrobalans with one of the iron salts or oxides. In Madras charcoal of the rice plant is employed in combination with lac and gum-arabic, and the Mohammedans generally prepare their ink from lampblack, gum-arabic, and the juice of the aloe. The following are the plants specially mentioned as adjuncts in the formation of inks:

(1) *Alnus nepalensis,* D. Don. Bark forms an ingredient in native red inks.

(2) *Cordia myxa* L. The unripe fruit is said to be used as a marking ink, though its color is less enduring than that from *Semecarpus.*

(3) *Phyllanthus emblica* L (Sanskrit *amaleka*). Fruits are largely employed in making black ink.

(4) *Semecarpus anacardium* L. (cf. Sino-Iranica, p. 482). The marking-nut tree bears a fruit with fleshy receptacle which contains a bitter and astringent substance universally used in India as a marking-ink, the juice being mixed with lime water as a mordant. Without the addition of lime it is often employed as ordinary writing-ink. As it is apt to cause severe inflammation, it has to be used with caution.

(5) *Terminalia belerica* and *T. chebula,* the unripe fruit of either species, or indeed of any *Terminalia,* is combined with iron in making ink.

The Siamese largely make use of Chinese ink, with which they write on long strips of gray paper made from tree-bast. A professional class of writers, called *alak,* avails itself ordinarily of a gum-resin dissolved in water, writing in yellow script on black paper. The Buddhist scriptures of the Siamese composed in Pali are written in Indian fashion on palm-leaves, the characters being incised by means of a style.

In ancient Camboja, according to the account of Chou Ta-kwan, who visited the country in the thirteenth century, official and private documents were written on pieces of deer-skin dyed black. They availed themselves for writing of a white clay, probably chalk, resembling the kaolin of China, moulding it into sticks, which were handled like pencils. Paper and ink were introduced from China and were used at an early date.

CHAPTER VI

THE HISTORY OF INK IN EGYPT, PALESTINE, GREECE, AND ITALY

IN a very interesting article entitled "The Physical Processes of Writing in the Early Orient and Their Relation to the Origin of the Alphabet" (*Journal of Semitic Languages*, Vol. XXXII, 1916), Professor J. H. Breasted observes with reference to an Egyptian representation of a noble of the thirteenth century B.C. with writing outfit, "In the use of this outfit the scribe made his own ink, mixing soot or lampblack with an aqueous solution of vegetable gum, which kept the insoluble black in suspension. This was done in one of the circular recesses shown on the little palette, and the pen was replenished from there. In the outer recess the scribe produced red ink in the same way, only using a red iron oxide instead of black. It was for this reason that we so often see the scribe with two pens behind his ear, one for the red and the other for the black ink. The red was used for the introductory words of a paragraph, and it was from this custom, as is well known, that the manuscripts of Europe received the so-called rubric, which has passed over into modern typographical usage."

Professor Breasted's researches endeavor to prove also that papyrus, pen, and ink were introduced from Egypt into Western Asia, beginning after 1100 B.C. In this respect Egypt's position in the West is identical with that of China in the East.

Ink is mentioned in the Old Testament but once: Jeremiah dictated his prophecies, and Baruch, his secretary, recorded them on a roll with ink (Jeremiah, XXXVI, 18: "He pronounced all these words unto me with his mouth, and I wrote them with ink in the book"), the word for the latter being *deyo*. Ezekiel (IX, 2, 3, 11) speaks of the ink-well of the scribe ("a man clothed with linen, with a writer's inkhorn by his side"). An allusion to writing without reference to ink occurs in Numbers (V, 23): "And the priest shall write these curses in a book."

In the New Testament ink is mentioned in three passages, as follows: "Forasmuch as ye are manifestly declared to be the epistle of Christ ministered by us, written not with ink, but with the Spirit of the Living God" (II Corinthians, III, 3). "Having many things to write unto you, I would not write with paper and ink: but I trust to come unto you and speak face to face" (II John, 12). "I had many things to write, but I will not with ink and pen write unto thee" (III John, 13). It is supposed, and with good reason, too, that the Jews during their sojourn in Egypt acquired their writing-materials from the Egyptians, and that the ink used by them was identical with that of ancient Egypt and Greece.

Among the Greeks ink was called *mélan* ("black") or *énkauston*. It varied according to the writing-material, and was distinct for parchment and papyrus. With the latter the Greeks adopted from the Egyptians both black and red ink. Two black pigments were known,—*trygínon mélan* made from dried wine-lees, and *elefántinon mélan* ("elephant's ink") made from burnt ivory. The latter method, according to Pliny, was invented by the painter Apelles, while Polygnotus and Micon, the most celebrated painters of Athens, made their black from grape-husk. In both cases it was soot pulverized with gum and dissolved in water. The proportions, according to the Materia Medica of Dioscorides (V, 182), were three parts of soot to one of gum.

This ink was more unctuous than that of modern times, and was, perhaps, more durable, resembling our printer's ink. Like Chinese ink it was solid and kept dry. Demosthenes reproaches Æschines for having been so poor in his youth that he allowed himself to sweep the school-building, to scrub the benches with a sponge, and rub the ink. According to Diocletianus' edict of Megalopolis, ink was sold in a dry state by the pound, the price being comparatively high, as the pound cost twelve denars.

Pliny (*Hist. nat.* XXXV, 25) writes that *atramentum* (literally, "black coloring substance") must be reckoned among the artificial pigments, but that it is also derived in two ways from the earth. Sometimes it is found exuding from the earth like the brine of salt-pits, while at other times an earth itself of a sulphurous color is sought for the purpose. Painters have been known to go so far as to dig up half-charred bones from the graves for the same purpose. This would make an inferior ivory-black. The earth mentioned afore is considered by Ajasson to be a deuto-sulphate of copper, a solution of which in gallic acid is still used for dyeing black. Beckmann (*Geschichte der Erfindungen,* Vol. IV, 1795, p. 491) regards these earths as two vitriolic products, a mud (*salsugo*) and a yellow vitriolic earth otherwise styled *misy.* Others think of oxide of iron or mangan; others, of brown-coal. It is evident that the Plinean account exhibits a most striking analogy with the earliest Chinese attempt to derive an ink from a black earth and other minerals.

It appears from Pliny's further data that the mineral ink was no longer used in his time, but was superseded by several artificial preparations from the soot yielded by the combustion of resin or pitch. This process had advanced to such an extent that factories were built on the principle of not allowing an escape for the smoke. The most esteemed black was prepared from the wood of the torch-pine. Vitruvius, in his work on Architecture (VII, 10) describes the factories alluded to by Pliny, in the translation of M. H. Morgan, thus:—

"A place is built like a Laconicum ('Laconian hall,' a room in a bathing establishment), and nicely finished in marble, smoothly polished. In front of it, a small furnace is constructed with vents into the Laconicum, and with a stokehole that can be very carefully closed to prevent the flames from escaping and being wasted. Resin is placed in the furnace. The force of the fire in burning it compels it to give out soot into the Laconicum through the vents, and the soot sticks to the walls and the curved vaulting. It is gathered from them, and some of it is mixed and worked with gum for use as writing ink, while the rest is mixed with size, and used on walls by fresco painters.

"But if these facilities are not at hand, we must meet the exigency as follows, so that the work may not be hindered by tedious delay. Burn shavings and splinters of pitch pine, and when they turn to charcoal, put them out, and pound them in a mortar with size. This will make a pretty black for fresco painting.

"Again, if the lees of wine are dried and roasted in an oven, and then ground up with size and applied to a wall, the result will be a color even more delightful than ordinary black; and the better the wine of which it is made, the better imitation it will give, not only of the color of ordinary black, but even of that of India ink."

According to Pliny, the lampblack ink was adulterated by mixing it with the ordinary soot from furnaces and baths, and this substance was also employed for writing.

Others, again, calcined dried wine-lees, saying that if the vine was originally of good quality, it will bear comparison with that of indicum (the "Indian ink" already discussed). The dyers prepared an ink from the black inflorescence that adheres to the brazen dye-pans. It was made also from logs of torch-pine burnt to charcoal and pounded in a mortar. The preparation of every kind of ink was completed by exposure to the sun; the black for writing receiving an admixture of gum; and that for coating walls, an admixture of glue. Black pigment that has been dissolved in vinegar, he concludes, is not easily effaced by washing. Beckmann annotates that our ink too is much improved by being exposed to the sun-rays in shallow vessels, and that our cotton-printers are familiar with the fact that vinegar solidifies the black. He himself made good ink by taking clear brewed beer-vinegar.

Alluding to the sepia, Pliny remarks that it has a wonderful property of secreting a black fluid, that, however, no color is prepared from it. He obviously means that no pigment for the use of painters was made from it, for Persius mentions sepia ink for purposes of writing. It was used as an ink especially in Africa. Cicero calls the animal *atramentum* ("ink"), in the same manner as the Chinese speak of the "ink-fish." The Greeks of the earlier period never mention the sepia ink; Aristotle knew the cuttle-fish well, but not its ink. In all probability its use was then unknown.

Both lampblack and sepia ink were principally used for papyrus, and could easily be removed completely by cleansing. Sepia ink can be almost entirely wiped out, and chemical reagents remain without effect. Haubenreisser, however, has sometimes employed a varnishing process with success (V. Gardthausen, *Das Buchwesen im Altertum*, p. 204). Hence in the epigrams of the Roman poets the sponge plays a conspicuous part; it was one of the regular implements of the scriba librarius: Martialis sends to his patron his latest verses accompanied by a sponge, in case they should not find favor with him. Augustus, when interrogated by his friends as to what had become of his tragedy "Ajax," responded that his Ajax had rushed not into his sword, but into the sponge ("waste-basket," as we would say in these days).

This feature shows plainly that the ink of the ancients must have been different in composition from that of the Chinese, which cannot be washed off or destroyed. An inkstand containing some ink, thick but still fluid, was found at Pompeii. Its viscous character was sometimes a ground of complaint, yet it was well adapted for writing on papyrus. For the smooth and permanent parchment, an ink prepared from oak-galls (Greek *kekis*, Latin *galla*) was preferred. In the course of centuries this ink assumes a fine yellowish brown rust tinge which is esteemed as a symptom of great age.

This ink marks another fundamental divergence between the East and the West, for it is not known in the East. The Chinese became acquainted with oak-galls as late as the T'ang period when they were introduced from Persia (*cf. Sino-Iranica*, pp. 367-369), and used the ink only occasionally under the Sung. In all probability gall-ink was invented in the anterior Orient, for the species of oak (chiefly *Quercus lusitanica* var. *infectoria*) on which the gall-wasp deposits its ova that form the excrescences known as galls grows in Asia Minor, Armenia, Syria, and Persia. Pliny is not yet acquainted with this ink, and it seems to have come into existence only during the first centuries of our era.

The use of galls for ink is mentioned by Philo of Byzantium in the second century, in a description of sympathetic ink, and by Martianus Capella in the fifth century. It has, moreover, been established by Sir H. Davy's experiments in the Herculanean manuscripts (*Phil. Trans.*, Vol. II, 1821, p. 205). Chardin (*Voyages en Perse*, 1721, Vol. II, p. 108) writes that the ink of the Persians is very black and made from galls, pounded carbon, and lampblack. It is greasy and thick like our printer's ink. They use inks of all colors, red and blue, and also write with gold.

The inkstands of the ancients were of various shapes, cylindrical or hexagonal, and of various materials, as terra-cotta, bronze, or bronze inlaid with silver and gold, and sometimes highly decorated. Some are provided with rings for attachment to the girdle. There are single and double inkstands, the latter being intended to contain both black and red ink.

Arabic science is largely based on that of the Greeks, and the Arabs' formula for ink is derived from Dioscorides. His work on materia medica was translated by Ibn al Baitar (1197-1248) in his *Treatise of Simples*, translated into French by L. Leclerc. Ink is treated in Vol. III, p. 297. It is called *midad* in Arabic, and in accordance with Dioscorides, is prepared from lampblack collected from pines (*dadi*), one ounce of gum being taken and mixed with three ounces of lampblack. The ink for painters' use is also made of resin-black.

CHAPTER VII

HISTORY OF PRINTING INK IN EUROPE TO THE MODERN ERA

THE earliest writing or printing was not dependent upon ink, as is evidenced by the clay tablets of the Assyrians and Babylonians produced more than four thousand years ago. Hundreds of these records have been collected and placed in the British and other museums, the most interesting specimen being one broken into eighteen pieces, which in assembled form narrates the story of the Great Flood.

In making these tablets (or "books" as they may be called), the Assyrians wrote, or printed, with cuneiform punches upon tablets of damp clay, which were afterwards baked hard for permanency. The punches were made of malleable copper, and the wedge-shaped characters cut upon the ends were in the Acadian language,—that used by the Chaldeans and Assyrians. It is interesting to note that these copper instruments bear a resemblance to the movable type in use throughout the world today. Thus, the first "books"—yea, the first library, consisting of many thousand tablets of baked clay—were produced by an "inkless" method of printing invented by the Assyrians. Although these nations were in a high state of culture, earnest in pursuing the sciences and perpetuating history by permanent records, they nevertheless adhered to this extremely crude method long after other nations had turned to the use of ink.

The introduction of writing with ink was a great triumph. It gave mankind a simple utility that all could manipulate. It led to the elimination of all the cumbersome and expensive materials previously used for keeping records. All subsequent materials (palm leaves, papyrus, parchment and paper) were devised for the one purpose of taking ink; and as these materials improved in quality, it became possible to make writing not only a mere matter of preserving records, but to make it a beautiful art.

This became especially noticeable when papyrus was superseded by parchment. Papyrus, used by the Egyptians twenty-five hundred years and more before the Christian era, served the world well and long, but it did not have an ideal writing surface. Made from the papyrus plant, a single-stemmed perennial of the sedge family growing on the Nile shores, it maintained itself as the chief material used in Egypt until about the tenth century A.D., and we find manuscripts written in Europe on imported papyrus as late as the eleventh century. But papyrus, being a fragile medium, failed to encourage the artist. It was made by cutting the plant's inner rind lengthwise into strips. On these another set of strips was laid transversely, and glued on with thick Nile water or other liquid. When pressed, hammered and dried, it presented a soft, smooth surface for ink, but the points of the writing instruments pierced or tore it easily, so that writing required the utmost caution and the scribes could venture to make only very light lines with little or no shading.

Despite this fragility, an extraordinary number of papyrus manuscripts have survived to our day, among them "The Book of the Dead," one of the oldest of the known Egyptian writings. This is a work of semi-sacred character, copies of which were placed in the tombs of their prominent dead. An example of this ancient manuscript is in the British Museum, and the ink has remained sufficiently unfaded to permit reading.

About two centuries before Christ, the Ptolemies, then ruling Egypt, forbade the exportation of papyrus into Greece, where the writing of manuscript rolls had become a great profession and, indeed, an inseparable part of Greek culture. Cut off from the supply of writing material, there was immediate necessity for a substitute, and one was found by reverting to a very old custom of preparing animal skins by washing, dressing and rubbing them smooth. Because tradition credits Eumenes II, King of Pergamum, with devising this expedient, the material was called "pergameno," from which comes the English term "parchment."

Parchment offered the early writers the most pleasing surface that had been produced to that time. Although it ran unequal in quality, because any carelessness in making it made very noticeable differences in the appearance of the writing, its surface invited good work. Firm enough to bear the most powerful strokes, yet so lovely in texture that the most delicate and microscopic writing or drawing could be applied to its full value, it so took ink that all the characters were glossy, brilliant, and wonderfully well defined.

In addition it was thoroughly durable, and thus was a great improvement over papyrus and other similar compositions of vegetable fibre. Papyrus could not be preserved save by rolling it carefully on a supporting cylinder; as it grew older and lost its moisture it became brittle and more perishable.

Therefore it may well be said that the general introduction of parchment created the first great inspiration for calligraphers and illuminators, who here found for the first time a surface which would take ink in a manner satisfactory to the lover of beauty. We may say that from this time dates the really scientific development of inks and colors for writing and, ultimately, printing purposes.

Parchments were made chiefly from the skins of sheep and calves. Their preparation called for decided craftsmanship and it was an expensive material even in the early days of cheaper labor. Any variation in the rubbing or polishing of a parchment sheet betrayed itself by variation of color and inferior appearance of the writing. Thus, while parchments were esteemed, the full development of the written and printed record could not proceed until a more economical material should be found that was at least approximately as good. This material was finally found in paper, but long after paper was introduced, parchment continued to be used for the more costly manuscripts. Even after the introduction of printing with types, parchment copies were taken off the press whenever it was desired to make a special appeal to rich lovers of books.

To this day, copies of early printed books are most highly prized if they are on vellum. Vellum was one of the finest parchments. It was made from the skins of young calves. Of the vellums, the most precious was uterine vellum, made from the skins of calves' intestines. It was the finest and thinnest of all, and was particularly desirable for the elaborate miniature painting done by famous illuminators. The brilliance of the black ink on fine vellum copies, both in manuscript books and printed books, remains the envy of modern practitioners; and the splendor of the gold and other colors has never been surpassed.

As Athens gradually took the place of Alexandria in the culture of the world, the Greek production of manuscripts assumed eminence. Many of the finest Greek manuscripts were written by slave scribes and copyists, who, through their educational contact, often developed literary talent, which in turn added to the learning and fame of all Greece.

Naturally the manufacture of ink became a highly important craft, and there is sufficient allusion to it in the works of early writers to indicate how important it was considered. But, from earliest times all crafts were jealous of their knowledge, and every effort was employed to preserve it as a mystery. We therefore have little definite knowledge of ink composition. A reference by Pliny says that the manuscript writers used an ink made of soot, charcoal and gum, but he gives no explanation as to how these materials were combined, nor does he say what fluid material was used to mix them. Still less is known of the composition of such colored inks as were used in the early centuries of manuscript books in Greece. We do know, however, that they were all writing or drawing inks pure and simple, and did not represent an approach to the printing ink which became necessary when the printed book took the place of the manuscript book.

The Greek manuscript was not, as a rule, highly ornamented. The art of decoration and ornamentation, and with it the art of decorative calligraphy, only began to flower when Italy became the producing place of manuscripts. This period arrived when Rome, in the course of time, took the place of Athens as the intellectual center of the world, just as Athens had displaced Alexandria. The time came when military and political subjection of Greece caused a gradual withering of the spirit which had given wings to its arts, and when Roman wealth and Roman glamour drew more and more of its thinkers and creators from their native land to the seat of the great mistress of the world. Thus the Eternal City became the chosen place of literature; and Romans of learning and culture soon established their own high standards for the art of writing.

Julius Cæsar may be said to have founded the first "newspaper," for it was he who originated the idea of issuing a daily bulletin containing the news of the Roman Senate. History informs us that the Acts of the Senate were "reported" by trained writers called "Tabularii," or inscribers of waxed tablets. These tablets were of wood or metal, with a wax-coated surface, on which notes were scratched with a stylus. The waxed surface of the tablet was protected by raised edges of wood or metal, like the frame of a modern school slate. Several of the tablets were hinged together in book fashion; in fact, there is every reason to believe that the modern printed book is simply an evolution of the Roman tablet "books" described herein. This fact is brought out even more clearly by the later Roman method of fastening together sheets of vellum-manuscript and enclosing them within beautifully carved covers of ivory.

The "Acts of the Senate" gradually developed into a publication of general news, known as the "Acts of the City." In reporting items for the "Acts of the Senate," the scribes used abbreviated forms of writing which enabled them to write very rapidly. It is said that Cæsar himself wrote his private letters in secret code, or an abbreviated form of writing, and this calligraphers assert was the beginning of modern shorthand writing.

Augustus Cæsar discontinued publication of the "Acts of the Senate," but encouraged the arts of writing and copying works of literature. At that time the classical works of Virgil and Horace, as well as the writings of other authors and poets, were produced in the form of manuscript rolls.

In Rome, as previously in Greece, practically all copying was done by slave labor, especially by educated slaves in the families of wealthy public men. The manner in which large editions of manuscript rolls were produced *simultaneously* by slave copyists, suggests in a way the modern method of quantity production by a series of presses. It was customary for the author, or reader, to read the original manuscript aloud to a hundred or more trained copyists, the entire group working as a unit in hand-lettering the words as quickly as read. It is recorded in history that Horace and his contemporaries had large editions of their original manuscripts duplicated in this manner, and the average cost of a small book so made (including papyrus, ink, and binding materials) was about 15 cents per copy in United States money. This is merely an estimate of the cost, but demonstrates, by the method employed, how manuscript rolls could be reproduced at very low cost.

The Romans, like the Greeks before them, for the most part continued to use papyrus as well as parchment, and both kinds of manuscript were rolled on rods or cylinders, generally of wood, but for exceptionally fine manuscripts, of ivory with a gold ball at either end. For the finest manuscripts purple-dyed parchment was sometimes utilized, and the lettering on this material was done in gold, or colored inks of brilliant hue.

Manuscript books, made of several sheets of parchment or vellum, bound together between covers, came into use about the year A.D. 300, or just before Constantine removed the Roman capital to Constantinople. After the removal of the Roman capital, Constantinople became a great center of learning. Here, during the next few centuries, many thousands of manuscript books were produced, some of which were the very essence of civilization and culture.

With the fall of the Western Empire the drift of literature was to the East, yet in the West remained the monks of the Christian church, who carried on the work of transcribing manuscripts, and were the beacon-lights of learning throughout the Dark Ages. The fire that consumed the splendid library at Constantinople destroyed more than 30,000 precious manuscripts, and would have been a disaster more fatal to knowledge than even the destruction of the Alexandrian library, if, fortunately, there had not been great zeal at that time among the monastic libraries of Europe for preserving, studying and enlarging their possessions. For many centuries these institutions not only kept knowledge alive, but developed to a truly exquisite point the beautiful arts of lettering and illumination.

Among the various orders of monks the office of scribe or copyist was always considered of great importance. The copyist usually worked in a room called the "scriptorium," and none but the Father Superior, scribes and copyists were allowed in this room. The tools used in making manuscript books consisted of quill pens, writing brushes, knives to cut quill pens, pumice stone to smooth

EARLY INK BALLS AND HAND PRESS

FROM AN OLD PRINT BY JOST AMMAN, 1568

the surface of parchment, styles and rulers to mark guide-lines on the material to be lettered, ink jars, and weights to hold sheets in position while the lettering was being done.

The copyist's work was usually that of making duplicate copies of manuscript books. He would first scratch guide-lines on the prepared parchment, with a style; also mark off the proper margins for a page, and leave blank spaces for illuminated initial letters. He would then write the words and lines in black ink. Although this ink was in liquid form, it had a heavy body and resembled the black writing ink used by the ancient Chinese. After the black lettering had been completed, and if the sheet was to be illuminated, it was passed on to an artist known as a "rubricator" or "illuminator." Many of the rare manuscript books are exquisitely illuminated in different colors, tints, and gold. As a general rule they were bound between thick wooden boards covered with leather. Specimens of these books are still in existence; also others having boards covered with carved ivory, and still others with covers of metal or ivory inlaid with colored enamel or precious stones.

It is a significant fact that the most beautiful and elaborate specimen of the illuminator's art in existence is a copy of the Gospels called the "Book of Kells," produced by Irish monks during the seventh century. This work, often termed the most beautiful book in the world, is notable for its precision in lettering, excellence of decoration, and variety of ornate initial letters.

The most famous manuscript books of the Middle Ages are, naturally, the liturgical works and works of related character. Aside from the religious enthusiasm of the monastic scribes, such books lent themselves, as they do still, to the "splendid manner" far beyond that which would seem suitable to books of any other class. Furthermore, the "splendid manner" had a very genuine and important usefulness. The Missals, Psalters and similar manuscript books were used in dim cathedrals, churches and cloisters, hence lettering of the largest size and most legible design, and ink of brilliant surface, were essential. Owing to this fact, the Missals and Psalters are generally the largest of all the manuscript books, some being quite enormous; and this tradition was followed during the first century of the printed book. The early printers also took over the traditions of that other beautiful devotional book, the *Book of Hours*. This, in contrast to the Missals and Psalters, had to be small so that it might be held easily by a dainty hand; and many of the richest of the manuscript books as well as of early printed books are these luxurious creations, which often had lavished on them everything that the arts of lettering, printing, decorating, illustrating, painting, binding and even goldsmithing and jewel-setting could contribute.

Inks and colors used for writing were radically different, in both chemical and physical properties, from the inks needed for printing. It is generally accepted that the early printers derived their ink formulas not from the scribes who produced the manuscript book, but from the Dutch and German painters. These men had discovered the value of linseed oil, well boiled down, for producing a varnish, and it was this boiled oil or varnish which was found by the early printer to be an absolutely necessary basis for printing ink, which in addition needed many other substances that the scribe working with pen or brush did not require.

Undoubtedly the history of printing ink goes back to the days when the Chinese first printed from engraved wooden blocks. Some historians maintain that a primitive method of printing was in use by the Chinese as early as a half century before the Christian era, probably done with the application of water-ink, as for centuries they had been using pigment stick inks in writing.

With the development of printing from wood blocks in China and Japan, it is reasonable to assume that some method of mixing the pigment with oil instead of water was evolved at an early stage. Certainly both the Chinese and Japanese had arrived at printing from wood blocks with oil colors several hundred years preceding the invention of typography. Specimens of their ancient printing in the various museums show traces of oil in the ink.

In the beginning of the fifteenth century the art of wood-block printing spread to the Christian nations, and it was not long until religious pictures, playing cards and even complete books were being produced from wood engravings. Practically all printing was done in black ink, and the pictorial work was hand-colored. That an excellent quality of black ink was used by these early block printers is evident from the appearance of specimens still in existence. In most instances the ink has remained a deep black with no sign of rubbing off.

The dispute as to whether Lourens Janszoon Coster (or Koster) of Haarlem, Holland, invented the art of printing with movable types, or whether the honor goes to Johannes Gutenberg, of Mainz, Germany, is a subject for the typographer rather than for the student of printing ink. There are no authentic examples of printing by Coster and we therefore have no opportunity to study what he may or may not have contributed to the science of ink-making.

In the case of Johannes Gutenberg we have enough reasonably well authenticated examples of his work to enable us to speak with some certainty about his ink. It may be assumed that he prepared his own; and it can be said with assurance that it was an admirable ink indeed. Although all the pages of the great forty-two line Bible are by no means equal in color, the irregularity is plainly due to the press work and not to the quality of the ink. A number of pages in the various examples of this beautiful work are undeniably gray; but the defective pages are insignificant as compared with the general beauty of impression, which is such that a Gutenberg Bible delights the eye of printer, artist, and book-lover. The ink was a true black; not glossy, but very firm and rich. Its durability is extraordinary, for these pages which were printed between 1450 and 1456 are as bright as if they had just come from the press.

While it is not certain that Gutenberg did any "color printing," many commentators insist on giving him credit for the first color printing, on the strength of the famous "Catholicon," and various fragments of fugitive printing. But the first really important and instructive color printing was undoubtedly a book printed in 1457 by Johann Fust and Peter Schöffer, of Mainz—the great folio Psalterium, a church psalter and one of the splendid liturgical books of all time, printed with a masterfully used large Missal Gothic type. It is famous for its magnificent initial letters printed in blue on red and in red on blue. All book-lovers have admired the great initial letter "B" which introduces the text. This ornamental letter, beautifully designed and cut, appears in most examples in blue on a red ornamental background three and one-half inches square, with a tracery of ornament in red running along the entire left-hand type margin. About two hundred and eighty smaller initials are scattered through the text and printed variously red and blue. The register is extraordinarily perfect—so perfect that there has been, and is, involved debate as to the method used by these two printers to apply their color and to obtain such marvellous exactness of application. This book, famous historically because it is the first book bearing printer's name, date and place, is of supreme interest as one of the most important examples extant of the use of colored printing ink as well as of the use of black ink.

The success of Fust and Schöffer in this form of printing did not immediately inspire their contemporaries or their immediate successors. In fact, Fust and Schöffer themselves abandoned the use of color in later works, and fell back on the original method of leaving initials blank for the hand-illuminator. Therefore we find a considerable period of printed books which serve as examples of the use of black ink alone, and this use of ink becomes more and more interesting as we approach the period of the illustrated printed book.

Günther Zainer, who set up a press in Augsburg about 1468, was among the first printers to produce illustrated books, the illustrations being reproduced through the medium of the wood cut. Naturally, new problems in printing ink arose with the illustrated book, and a most interesting group of craftsmen appeared in the region contiguous to Augsburg. About 1470 Heinrich Keffer opened a printing office at Nuremberg. A few years later John Sensenschmidt founded a press at Bamberg, and in 1481 produced his now famous *Missal,* printed in a fine, large Missal Gothic type, and having large, pictorial initial letters printed in red and black ink. In 1473 Anthony Koberger started a printing establishment at Nuremberg, which became so successful that he operated twenty-four hand-presses. He printed at least twelve editions of the Bible in Latin, and one large edition in German. Koberger was indeed a progressive master printer, which is indicated by the fact that he eventually opened printing establishments in Basel, Switzerland, and in Lyons, France.

The history of the spread of typography from Germany to other countries reads like a romance. "Beyond the Alps lies Italy" is a famous quotation which might well have been in the minds of some of the early German printers, for it was to Italy that several German printers made their way during the fifteenth century. The first printers to reach Italy were Conrad Sweynheym (Sweinheim) and Arnold Pannartz. In 1465 they arrived at a monastery located in Subiaco, a village in the outskirts of Rome. They brought with them a cart, on which was loaded a press, fonts of type, bundles of paper, and a supply of printing ink. The cardinal in charge of the monastery received the pair of wandering printers kindly, and after seeing specimens of their work, came to an agreement with them. The little printing plant was set up in the monastery and here during the next two years a number of church and literary books were turned out complete. In 1467, Sweynheym and Pannartz removed their printing office to Rome. In that city, during a period of about five years, a large number of classical books came from their press, but later on the firm had difficulty in disposing of its product at profitable prices, and as a result the business was discontinued.

Soon after Sweynheym and Pannartz had established their press at Subiaco, another German printer—Ulrich Hahn—started a printing business in Rome, and this competition may have been responsible for the failure of the first firm after it had removed to that city.

Venice then began to compete with Rome as a printing center and soon won supremacy. Indeed in Venice there unfolded what may be called the flower of printing. The craftsmen who were drawn to the great and immensely rich city produced, on the whole, the most beautiful printing the world had ever seen. It is enough to mention the names de Spira, Jenson, Ratdoldt, and Aldus. The first typographers and printers in Venice were the brothers John and Wendelin, whose imprints are "de Spire" and "de Spira" denoting that they were from Speyer, Germany. They established their press in 1469, using a good German letter only slightly reminiscent of the German Gothic. John's printing was so esteemed that Venice accorded him exclusive printing rights, but the monopoly, if ever exercised, was not enjoyed long, as he died in 1470. This same year marked the entry into Venice of Nicolas Jenson, the illustrious Frenchman who designed one of the greatly beautiful Roman typefaces, and whose fame remains secure as a printer of noble books.

The ink used by these men was excellent, Jenson's books showing an intense black, velvety and glossy, which has faded slightly or not at all in all these centuries, and which shows smudging or other defective working qualities in only very few slight instances. Erhard Ratdoldt of Augsburg, who began printing in 1476, is particularly interesting to the student of ink because he not only had a good black, but was a daring innovator in the use of colors. Initials and ornaments as well as illustrations in the wonderful Ratdoldt books are printed in brown, blue, red, olive, yellow, gold, and other colors, so that some of his pages are almost as vivid as a highly hand-illuminated manuscript. When he returned to Germany to print liturgical works at the invitation of ecclesiastical authorities he developed his color printing to a still further and remarkable extent. There is no more delightful study for the book-lover than an examination of the splendid Ratdoldt initials, the famous "literæ florentes" which remain among the best achievements of old book ornamentation.

Before the year 1500 more than two hundred printing offices were in Venice, and by 1500 it is said that one million volumes had been printed in that city. Bernardo Cennini introduced typographic printing into Florence in 1471. Johann Neumeister, a pupil of Gutenberg, started a small printing office in Foligno, a little town of Italy, in 1470.

Another of Gutenberg's workmen, Berthold Ruppel, became the first printer of Switzerland, when in 1468 he set up a press at Basel. From the city of Basel the art of typography gradually extended to France. In 1470 Ulrich Gering, Martin Crantz and Michel Freiburger (three German printers who had been working in the city of Basel) went to Paris and there began printing under the patronage of two members of Sorbonne University. Henri Estienne, a skilled typographer, settled in Paris in 1502, and established a well-equipped printing office. Later his business was taken over by his son, Robert, who eventually was patronized by the King of France.

The history of printing in the Netherlands is obscure on many important points, and it is not definitely known if typography was practised there previous to 1473, when a press was established at Alost. It is a well-known fact that one Colard Mansion had a printing office at Bruges in 1475. Christopher Plantin, a Frenchman, began printing from type at Antwerp in 1555. His work was of the finest character, and his printing shop was considered so important that it has been preserved and is today a museum in the city of Antwerp. The claim has been made that Haarlem was the birthplace of typography, and that Lourens Janszoon Coster of that city was the inventor of movable type, but the earliest dated book known to have been printed in Haarlem is one of 1483, the year when Johannes Andriesson had a press there.

William Caxton, of London, was the first typographic printer of England, and credit goes to him for having produced the first book printed in the English language. Before that work was accomplished, Caxton lived at Bruges. He had been elected Governor of the English Nation in the Low Countries, and to please his patroness, the Duchess of Burgundy, he undertook the translation of *Les Recueil des Histoires de Troye.* He produced it in manuscript under the English title *The Recuyell of the Hystoryes of Troye.* The work was begun in 1468 and completed three years later, and the demand for copies was so great that Caxton studied ways and means of duplication. Colard Mansion was then the only printer in Bruges, and Caxton went to him to learn about the printing of his book.

In this mission Caxton was highly successful, and though he was then fifty years old, he soon learned the entire printing trade—from casting type and setting it up, to printing sheets on a hand-press. The "Recuyell" had no printed date, but was probably printed late in the year 1475.

Caxton returned to England and late in 1476 or early in 1477 began printing in the vicinity of Westminster Abbey. The first book by Caxton with a printed date was *The Dictes or Sayengis of the Philosophres,* completed in November, 1477. There is no doubt that Caxton made his own printing ink, and moreover that it was of good quality, as proved by the clear, "black" copies which still remain.

In Scotland typographic printing was introduced by Andrew Myllar and Walter Chepman, their first book being printed in 1508. These printers set up a press at Edinburgh, and were granted a license by King James IV.

The first typographic printer of Ireland was Humphrey Powell, who went there from England and founded a printing office at Dublin in 1551. Powell removed with him from England a press, fonts of type, and other materials essential for printing, including a supply of printing ink.

In America the new art of typography apparently was first practised at Mexico City, Mexico, under the direction of Viceroy Mendoza, in 1536. The exclusive printing privilege was given by royal grant to Johannes (Juan in Spanish imprints) Cromburger of Seville, Spain. He remained in Spain and established his Mexican press through a representative, presumably his foreman, Juan Pablos, also termed Paulus in some records. The general modern opinion is that Pablos printed the first book in 1539: *Breve y Más Compendiosa Doctrina Christiana en la Lengua Mexicana e Castellana.* Some commentators

MIXING INK AND INKING TYPE

SCENE IN AN EARLY PRINTING SHOP, FROM A PRINT BY ABRAHAM VON WERDT, ABOUT 1646

hold that various undated books precede this. A recent European treatise declares that the first book in Mexico (and thus the first book in America) was printed in the Cromburger shop in 1537.

The general manner in which many of the early printers made black printing ink was first to boil linseed oil in a small pot over a wood fire until it obtained the consistency required. Pitch was then burned in a kind of iron tent, the smoke from the burning pitch leaving a heavy deposit of black soot on the sides of the tent. The black soot was then scraped off and mixed with linseed oil with the aid of a muller and stone.

When the artist-printers of the fifteenth and early sixteenth centuries were replaced by others who did not always possess the same talent, and who practised printing as a trade rather than as an art, the quality of printing ink became inferior in proportion as the quality of the typography deteriorated. Thereafter the history of printing is a history of almost continuous mutation. Printing declined and revived with new strength and vigor in alternate periods. Throughout the centuries from the seventeenth to our own, we can follow these successive declinations and resurrections.

Thus we can make no sweeping statement as to the quality of the early inks. The best were extraordinarily good and are still deserving of our admiration and study. The poor ones were poor indeed. Theodore L. DeVinne, dean of modern American printing, in his book *The Invention of Printing* says:

"The general impression that early printing ink is blacker and brighter than modern ink is not always correct. Early ink seems blacker, because it is shown in greater quantity, for the early types were large, or broader face, without hair lines, and could be overcolored without disadvantage.

"The same ink applied to the small thin Roman type of our time would seem dull and gray. The microscopic examination of early ink will show that the black is not fine and not thoroughly mixed with proper drying oil. But this imperfection is comparatively unimportant. It is a graver fault in some early inks that they are not firmly fixed to the paper."

CHAPTER VIII

THE DEVELOPMENT OF THE PRINTING-INK INDUSTRY

MANY books have been written on the history and art of printing, and additional works frequently appear, yet little has ever been said on the subject of *Printing Ink*. This may at first not seem a serious omission, but when one realizes that Printing Ink is absolutely essential to Printing, its importance is obvious. On the ink has depended the satisfactory preservation of all the beauties that the typographer, the illustrator, the decorator, and the pressman lavished on their work.

Records show conclusively that the earliest typographic printers made their own inks. In case of a partnership, the one entrusted with the making of ink usually furnished his own ingredients, but in return received more than an equal share of the profits. Historical notes on the subject show interesting romantic incidents connected with the birth of this industry.

When ready to manufacture a new batch of ink for the season, the master printer, with his assistants and apprentices, their families and friends, would take a holiday. A fire would be built, over which would be hung a huge iron pot for the boiling of linseed oil. The merrymakers would gather around, and the banquet, or picnic dinner, included bread that had been roasted, or fried, in the hot linseed oil. Later on, by means of muller and slab, pigment was ground with the boiled oil, and a good grade of printing ink was thus produced.

Early German printing ink manufacturers produced black ink of the finest quality from linseed oil and lamp-black, while early English ink makers added portions of rosin and mineral oil to rather a poor grade of linseed oil. The best linseed oil varnish was, of course, produced by a long period of boiling; in fact, practically all printing ink varnishes at that time were made by heating the oil to a point where the vapors would ignite from the heat of a red-hot iron held nearby.

Moxon, in his *Mechanick Exercises,* published in 1683, refers to the troubles experienced by English printers in the seventeenth century:

"The providing of a good inck, or rather a good varnish for inck, is none of the least incumbent cares upon our master printers, though custom has made it so here in England; for the process of making inck being as both laborious to the body, as noysom and ungrateful to the sence, and by several odd accidents dangerous of firing the place it is made in, our English master printers do generally discharge themselves of that trouble; and instead of having good inck, content themselves that they pay an inck maker for good inck, which may yet be better or worse according to the conscience of the inck maker."

As a prominent writer has well said, this is not a very good testimonial for the ink maker of Charles II's day, but according to Moxon, the printer of the Stuart period was little better, and we are told "that he (the printer) would rather hazard the reception of an ill printed sheet than take the pains to amend it, satisfying himself that he can lay the blame on the inck maker."

Some of the manufactured ink referred to by Moxon was probably among the equipment of the first printing plant established in English America, brought from England to Cambridge, Massachusetts, in 1638, and placed in charge of Stephen Daye. The first book produced by Daye (1640) was the *Booke of Psalmes,* or better known as the *Bay Psalm Book,* which unfortunately is considered a very poor specimen of printing. Stephen Daye was succeeded by Samuel Green, who in 1662 was required to give the commissioners an "account of utensils for Printing belonging to the corporation." The following is an item from that account:

"Item two barrells of Inke, 3 Chases, 2 composing stickes, one ley brush, 2 candlesticks one for the Case the other for the Presse."

The two barrels of ink mentioned were no doubt imported from England, as there is nothing to indicate that either Daye or Green made his own ink.

Pioneer American printers, thus sparsely equipped, obtained their inks from England from regular ink manufacturers. It is interesting to note, however, that two of the best known American printers, Christopher Saur and Benjamin Franklin, made their own ink.

John F. Watson, in his *Annals of Philadelphia and Pennsylvania,* (published in 1842) has presented illuminating notes concerning Christopher Saur (or "Sower") and Benjamin Franklin. One of these notes is as follows: "Both Sower and B. Franklin were ingenious in their profession, made their own ink, and cut their own wood cuts before either of them (ink or wood cuts) were attempted by others."

Christopher Saur founded a printing office in Germantown, Pennsylvania (now a section of Philadelphia), and in 1742 cast the first type made in America. He also produced the first German Bible in America (1743), and the first religious magazine, *Das Geistliches Magazien,* in 1746.

Benjamin Franklin in 1728 established a printing business in Philadelphia which lives to this day. It was while working at the printing trade in London that Franklin had his first practical experience at ink-making. He had also studied type founding, and after returning to Philadelphia and starting in business for himself, conducted further experiments with ink manufacture, and later on cast a quantity of type. The many specimens of Franklin's printing which still exist are notable for both their handsome typography and their good presswork, and all show the use of fine printing ink.

The simplest methods of manufacture were employed by Saur and Franklin, and their efforts must have been confined to the making of black inks by grinding together with muller stones the linseed oil and lampblack. Saur had probably seen ink made in this manner when he lived in Germany, and Franklin had seen much the same process while working in London. In any event, both knew how to make printing ink of good quality, and what they may not have known about the process at first was soon learned by experience.

One of the first establishments of England devoted exclusively to the manufacture of printing inks was that founded by William Blackwell, in King Street, Clerkenwell, in the year 1755. Prior to that date English printers, with their limited facilities and crude, undeveloped methods, had invariably made their own inks, and the results were far from satisfactory. Thus when Mr. Blackwell started in the business of manufacturing really good printing ink for the printing trade, he found a ready market for his product.

In 1785 the *London Times* was started and Mr. Blackwell was called upon to supply the ink for that paper. The business expanded and Mr. Blackwell took into partnership a man named J. Farnell. The firm name then became Blackwell & Farnell, and continued under this style for a period of approximately fifty years, although the founder of the business had died only a few years after the partnership had been formed.

In the year 1850 George Moss became a member of the firm, which at that time was called Blackwell & Company. Mr. Moss died in 1871, and during the same year the works were moved to Stratford. In 1879 Frederick William Moss, son of George Moss, entered the company. In 1909 Blackwell & Company became a limited firm, with Frederick Moss as chairman, a position which he still holds at the time of this writing.

Among the first American printers to manufacture good printing inks were Rogers & Fowle, of Boston. This firm supplied the trade with ink during the years 1742 to 1750. During the Revolutionary War printers and publishers of the United States experienced considerable difficulty, and it is related that through the lack of imported linseed oil they were forced to use fish oil as a vehicle for the pigment.

Isaiah Thomas, of Worcester, Massachusetts, and Mathew Carey, of Philadelphia, are both known to have produced printing ink of excellent quality before the year 1800. The principal reason why many of the early printers made their own inks was because of the uncertainty and irregularity of shipments from England. In colonial days a shipment of ink from London, or any foreign port, was often several months in arriving.

What is said to have been the first regular printing-ink manufacturing plant established in America was that founded by Charles Johnson in Philadelphia in 1804, who shortly thereafter took into partnership a man named Wrigley. It would seem, however, from notes in Lockwood's *American Dictionary of Printing and Bookmaking,* that prior to the opening of the Johnson factory several other printing ink firms had been in business. The partnership of Johnson & Wrigley was dissolved in 1814. The Johnson plant was destroyed by fire in 1816, with a loss of $900, and was then rebuilt on a larger scale. About this time Charles Johnson retired from business and was succeeded by his brother Jacob, who in turn was succeeded by Charles Eneu Johnson. The company was incorporated in 1883, and is still in business.

It is an interesting fact that in the year 1805 the Faustus Association, of Boston, an organization of employing printers, recommended to its members the ink made by J. M. Dunham, of Cambridge, Massachusetts.

About this time William Prout began the manufacture of printing ink in New York, founding a business which continued until the beginning of the Civil War.

In 1816 George Mather and J. W. Donnington, two printing pressmen of New York, started an ink manufacturing business in that city. Donnington withdrew from the firm a year later, but the business proved successful, and an "offshoot" of it was the plant later established by J. G. Lightbody.

In 1848 Horace Dwight Wade, a chemist and druggist, of Rochester, New York, conceived the idea of substituting rosin oil for linseed oil in the manufacture of printing ink. He sold his drug business in 1850, and two years later began the manufacture of printing ink in New York City.

Among the notable printing ink manufacturers of Philadelphia was Charles E. Robinson, who in 1845 started the "Grays Ferry Printing Ink Works," located at Grays Ferry Road and Thirty-third Street. Soon after the erection of his plant, covering an entire city block, Mr. Robinson admitted his brother, John G. Robinson, into the firm, which was then styled C. E. Robinson & Brother. Desiring to further extend their business, the brothers then admitted a Mr. Pratt, who had been formerly associated with the H. D. Wade Company, of New York, and the firm name was changed to Pratt & Robinson. In 1898 the business was sold to Thomas Robb, James Rodgers and Alexander Scott, all three of whom had been employed by the old company for many years. The firm name now became Robb, Rodgers & Scott, and this company continued in business until the year 1900. Later, when Mr. Scott died, James McCutcheon, who had been in the employ of the company for a long time, purchased Mr. Scott's interests, and the new partnership continued until 1906 when Mr. McCutcheon withdrew. The firm of Robb & Rodgers continued for some years after this, or until the death of Mr. Rodgers. Mr. Robb then closed the business. Robert McCutcheon joined his brother James in the year 1906, and the new firm under the name of McCutcheon Brothers opened an ink factory at 103 N. Marshall Street. This firm was incorporated in 1910 under the style of McCutcheon Brothers & Quality, Inc., and is still in business.

Another old Philadelphia printing-ink factory was that started by J. K. Wright in 1858, the firm name being J. K. Wright & Company. This company was incorporated in 1900. In 1904 the founder died, and was succeeded by his brother, George N. Wright. This firm is still in business under the name of The J. K. Wright Printing Ink Company.

Colored printing inks, with the exception of vermilion, were not manufactured to any extent in the United States prior to the year 1840. It was the practice of American printers to import special colored inks from Germany and England, although some printers made their own colors by mixing dry pigments with linseed oil. Booth, of New York, began the manufacture of colored inks in 1840, and a short time afterwards Wade also started making this line. It was many years before pictorial color printing was done on a large scale, and as yet the halftone and process color work were things undreamed of.

The art of printing from stone in the lithographic manner was discovered by Alois Senefelder, of Munich, Bavaria, in 1793, but it was several years later before he had perfected this invention. In the year 1817 Senefelder wrote and published his excellent book entitled *The Invention of Lithography*, which is today considered a classic among technical works of its class. In reviewing the results of his invention during the decade that had elapsed, Senefelder remarks: "Everything that I and others have done since then [the time of his discovery] are only improvements. Everything still rests on the same principle: ink of wax, soaps, etc., then gum, aqua fortis or another acid of which none has the advantage over the others; further oil, varnish and lampblack,—

these are, ever and in the same manner, the chief elements of stone-printing as they were then."

One chapter of this book is on "Crayon, Etching and Color," giving formulas for litho inks, and includes full particulars about the manufacture of "Chemical Ink," (litho); Hard Borax Ink, Fluid Ink, Transfer Ink, Crayon, etc. The well-known method of making printing ink with linseed oil and lampblack is clearly explained.

T. C. Hansard in his *Typographia,* published in 1825, tells how John Baskerville of England had in the previous century made ink of superior quality:

"He took of the finest and oldest linseed oil three gallons. This was put into a vessel capable of holding four times the quantity, and boiled with a long-continued fire till it acquired a certain thickness or tenacity, according to the quality of the work it was intended to print, which was judged by putting a small quantity upon a stone to cool, and then taking it up between the finger and thumb; on opening which, if it drew into a thread an inch long or more, it was considered sufficiently boiled. This mode of boiling can only be acquired by long practice, and required particular skill and care in the person who superintends the operation, as, for want of this, the most serious consequences may occur, and have very frequently occurred. The oil thus prepared was suffered to cool, and had then a small quantity of black or amber rosin dissolved in it, after which it was allowed to cool some months to subside; it was then mixed with the finest black that could be secured, to a proper thickness and ground for use."

William Savage, a distinguished London printer, in 1832 published a book entitled *Preparations of Printing Inks both Black and Colored,* in which he gave the with newly boiled oil. This for the reason that an old oil is comparatively free from "foots" or sediment. It "polymerizes," as an oil chemist would put it technically. The early ink makers also learned by experiments that various grades of oil or varnish could be produced according to the length of time devoted to the boiling process. Various grades of varnish were also produced by the addition of driers.

In view of the fact that earth colors were known to the ancients, and that pure earth pigments were used in painting pottery and other works of art centuries before the Christian era, it seems certain that earth colors were employed in the manufacture of the first printing ink. Both the Egyptians and the Chinese had at their disposal an array of earth pigments, including black, white, red, blue, green, brown and yellow, and by mixing any of these colors with an oil, paint of the finest quality was produced. The first printing ink was black, made by the use of either earth pigment or lampblack, but as time advanced, the early typographic printers made inks of various bright colors, but only to a limited extent, black always being the prevalent and most useful color.

During the seventeenth century practically all colored printing inks produced were made by the use of pure earth pigments. The discovery of the now famous "Prussian blue" was made by Diesbach, a color manufacturer, in the eighteenth century, and this discovery eventually led to the development of the "iron blues," or chemically produced pigments which range from pale blue to deep purple. The iron blues, of which Prussian blue is the most prominent, are known to the printing trade by such familiar names as "Bronze blue," "Milori blue," "Chinese blue," etc. Diesbach's discovery is based on the chemical test that when a ferrous or ferric salt is added to the potassium ferro-cyanid, a pigment is precipitated. The color of this pigment may vary from pale blue to purple, according to the chemical process used. The iron blues are permanent colors and are being largely used in the manufacture of printing inks today. (See chapter entitled "Colored Pigments for Printing Ink—Natural and Artificial.")

One of the greatest boons to the printing-ink industry was the discovery of coal-tar colors during the middle of the nineteenth century. Before the introduction of coal-tar dyes, the lakes used in manufacturing colored printing inks were made from natural dyestuffs, such as sapan wood, fustic, cochineal, logwood, flavin, and so forth. These natural dyes were expensive and added much to the cost of printing ink in which they were used. In recent years the natural lakes have been superseded by those made from coal-tar dyes, which are less costly and which also have greater staining quality and greater brilliancy, though often lacking permanency.

The coal-tar colors are very numerous; they include almost every shade of color required in the manufacture of printing inks. The process of producing the dyes is very complicated, and it is only by repeated chemical changes that the various lakes are obtained. Some of these colors are sunfast, but others unfortunately will rapidly fade under strong light. All of these colors, however, are suitable for the greater amount of color printing being produced today. It is important to note that coal-tar lakes are now being used to the greatest advantage in the manufacture of special inks required for three-color and four-color processes of pictorial printing.

The halftone was invented in 1880, but several years were required to perfect this process. The halftone eventually proved to be a tremendous aid to the development of the printing business, as by its use it was possible to print faithful reproductions of photographs in magazines, newspapers, catalogues and all kinds of advertising literature. The printing-ink manufacturing concerns were equal to the task of making ink suitable for the finest halftone printing on coated and enamelled papers. Process color printing from halftones was the next important accomplishment, and here again ink manufacturers were quick to perfect special inks required for this class of work.

Innumerable patents have been taken out in this and foreign countries on alleged improvements in the manufacture of printing inks. The inventors usually thought they had discovered some by-product, in another line of manufacture, that could be used as a substitute for one of the ingredients commonly used in printing ink. One of the early patents was that of a Brooklyn man who introduced colophonic tar into ink. Many of these laboratory experiments, in the hope of producing an improvement in inks, have cost investors fortunes when they attempted to manufacture on a large scale and prove it practicable.

Probably no article of manufacture in the whole world has gone through so many changes during the past fifty years as printing ink. This is due to a number of causes, chiefly the rapidly multiplying number of substances on which printing is used, from the printing on wood to be made into boxes and cases of all kinds, to the printing of flags of all nations and the designs on the finest fabrics. Then too, new kinds of paper stock are constantly coming into use, and it is an old rule that the ink must be made to fit the paper stock. Besides this, the kinds of printing presses vary so much. The increasing speed of presses demands inks of different quality and consistency from those heretofore required. It can be understood that even black printing inks must be of different consistency and "tack" for proof presses and for jobbers; entirely different for cylinder presses from fast rotary magazine presses, and again different for web perfecting newspaper presses.

An interesting modern novelty in printing is shown by the use of special machinery working automatically to weigh, pack, wrap and print various articles of merchandise in one single operation. American ingenuity has developed wonderful things in this direction. Cigarettes, box and carton packages of different sizes, wall paper, playing cards, cereals and fruit among many such staples, are put into marketable shape in an astonishingly short space of time. It is simply marvellous what is being done in a business way in following these methods of packing and printing. Special inks are, of course, necessary for such uses, and often they must be prepared to be absolutely pure and harmless for use in connection with food products. An immense quantity of ink is used in this method of printing.

The "Rule of Thumb" methods of ink-making practised in the past have largely disappeared. Twentieth-century printing inks are laboratory problems that require the constant study and experiments of highly trained and specialized chemists. Printing inks today begin in the laboratory and are followed by chemists through the factories to the printing presses, and even the printed product is subjected to microscopic examination. All progressive ink manufacturers maintain efficient laboratories, some of them extensive and employing twenty or more chemists and assistants, where every ingredient entering into the manufacture of ink is carefully analyzed before it is used. For of what use would be the best ink formula if the ingredients entering therein were not up to the required standard? Samples of the ink are sent to the laboratory during the process of manufacture and finally the finished product is tried out on presses in the factory on the precise material on which the printing ink is afterward to be used. So that printing-ink manufacture has become a chemists' business at present, with the prospect of even greater dependence on chemistry in the future. Even now the chemists in an ink laboratory are divided into those who specialize in oils and varnishes and others who give their attention solely to colors.

Among the many other factors which have contributed to the remarkable development of the printing and publishing business during the last fifty years are the perfecting press, the mammoth web newspaper press, the linotype composing machine and the modern, high-speed rotary presses. Mention should also be made of the rotary offset press and the rotary intaglio press. These wonderful mechanical improvements have revolutionized the printing and publishing industry, and it is only fair to state that the printing-ink industry has kept pace in this grand march of progress.

To give an idea of modern consumption of printing ink, I can state authoritatively that one single newspaper, a morning daily in New York City, consumes every single day in the year more than 8,000 pounds, or over 4 tons, of ink. This newspaper is one of the larger, though probably not the largest user in New York or in the

United States, but this serves as a basis on which one can form some idea of the immense quantity consumed, and the daily requirements constantly increasing.

The Department of Commerce announces the production of printing ink in the United States in 1921, as valued at $20,869,477. In the year 1923 the production of printing ink was valued at $29,412,122, an increase of 40.9 per cent as compared with 1921. This shows the great importance of printing ink in our industries and the enormous increase in production during the year 1923. The year 1925 will undoubtedly show a steady growth, and likely equal the 40 per cent increased output over the year 1923. The figures given are from the last biennial census of the United States as compiled by the Bureau of the Census at Washington.

CHAPTER IX

METHODS OF PRINTING NOW IN GENERAL USE AND OBSERVATIONS ABOUT INKS

BROADLY speaking, there are three distinct methods of printing in general use throughout the world today, but each of these methods is utilized in many different ways. 1. Typographic printing, or relief printing of any kind from a form or plate having a printing surface in relief. For example, a form of type has a printing surface consisting of characters cut or cast in high relief. 2. Intaglio printing, a term which means printing from *below* the surface of an engraved plate, An intaglio engraving is opposed to a relief engraving in that its printing design is sunk below the flat surface. 3. Lithography, a term which refers to printing from the flat surface of a chemically prepared stone or plate, the printing design being neither in relief nor incised below the surface.

By means of these three different methods a large variety of printing is done, including the most beautiful color pictorial work. However, each process is particularly adapted to a certain range of work, and the history of the graphic arts clearly indicates that each of these three fundamental methods shall continue to have its uses in the future, despite the radical changes which have been made in printing processes in the past. To put this statement in more definite form,—there shall always remain the need for typographic printing just as there shall always be uses for intaglio printing and lithography.

Typographic printing still retains its lead over all other methods of printing, although the art of typography is nearly five hundred years old, and a considerable amount of printing is still done from engraved wood blocks. The so-called "wood-cut" has never lost its artistic value; in fact, during recent years the art of engraving on wood blocks has been revived and today beautiful examples of this method of pictorial printing appear in magazines, booklets and advertising literature. The greater portion of all modern pictorial work done on typographic presses is, however, produced from metal plates, such as half-tones, line engravings and zinc etchings.

Typography, or printing from forms of type, can be subdivided into two methods. 1. Forms of movable type composed by hand. 2. Forms of type produced on composing machines, of which there are several makes and styles. Hand composition is done both with regular foundry type and with movable type cast on machines of the type-casting group. Composing machines of the Linotype class produce solid lines of type. The Monotype machine, consisting of keyboard and caster, produces movable type set up and spaced into columns or forms. As a general rule, straight text matter is set on the Monotype machine, while the Linotype machine is capable of turning out both text matter and display composition.

Typographic printing is done not only from regular forms of type, but also from electrotypes and stereotypes of the original forms. In these days, practically all the large daily newspapers are printed from stereotype plates, while the larger magazines are printed from electrotypes. The major portion of book work is also printed from electrotypes of the original forms.

Many different makes and styles of presses are employed for typographic printing, including platen presses, automatic high-speed job presses of the cylinder type, large-size cylinder presses, two-color cylinder presses, one-color and multi-color rotary magazine presses, and others, including the mammoth web presses which are used in the production of newspapers. In addition to these there are special types of both flat-bed and rotary presses which print in several colors at one operation. Among the comparatively new types of automatic presses used in the magazine publishing field is a sheet-fed rotary press, printing two, three or four colors, to absolutely close register, at one operation. This is called "wet" printing because one color is immediately printed over another.

The term *typographic printing* applies to all kinds of work handled on typographic presses, such as halftone work printed in one color; process color work printed from halftones in two, three or four colors; one color printing from line engravings or zinc etchings; multi-color printing from line engravings; and all kinds of printing produced from electrotypes and stereotypes. Copper electrotypes are generally employed for printing in black ink, while nickeltypes are widely used for color printing, for the reason that the nickeltypes are not affected in any manner by certain pigments used in the manufacture of colored printing inks.

Intaglio Printing. This term is applicable to a number of different processes of printing from an intaglio engraved plate, including steel and copper plate printing, steel die stamping and embossing, and the comparatively new so-called "Rotogravure" method. The history of intaglio printing apparently goes back to the year 1452 when a Florentine goldsmith, named Maso Finiguerra, is said to have accidentally discovered the art of etching a metal plate. This discovery led up to all the various intaglio printing methods which are in practical use today.

The early intaglio printers confined their efforts to the etching of copper and steel plates to be used for the reproduction of fine art subjects, such as pictures of famous cathedrals, portraits, illustrations for books and the like. Later on this art extended into more commercial fields, and in course of time such things as paper money, certificates, diplomas and business announcements were being produced from steel plates. At the present time the paper money and postage stamps of the principal countries of the world are printed by the intaglio method. By the same method many other kinds of work are produced in untold quantities, including business stationery, greeting cards, bonds, social stationery, calling cards, wedding invitations, etc.

Engraved copper plates, being softer than steel plates, and cheaper to produce, are used mainly for short runs of social work, such as calling cards, announcements, "at home" cards, etc. Engraved steel plates are generally made for the printing of longer runs, and for the finest classes of work, such as book-plates, business cards, letterheads, portraits and reproductions of art subjects. The steel plates are also made for the printing of large-size pictures, college diplomas, paper money, bonds and certificates.

What is known as the die-stamping process differs from the ordinary method of steel and copper plate printing in that the steel plates for die-printing are engraved extra deep. Moreover, a steel die is made to do printing and embossing simultaneously. A piece of printing produced from a steel die, like a letterhead design, for example, will have the lettering and other detail standing up in high relief. The steel dies are used for die-stamping business stationery, greeting cards, menu cards, booklet covers, programme covers, envelope corner cards, heraldic designs for social stationery, and other fine work of this description. Die-stamping is done in one color for many lines of work. It is also done in two or more colors, when a separate die must be engraved for each color.

Plate printing and die-stamping are done on various makes and styles of presses, all of which are different from any of the typographic presses in service. The old-fashioned "D" roller plate press, operated by hand power, is still used in the production of steel and copper plate printing, but particularly for short runs. The new-style power plate and die presses are employed for long runs. Hand stamping presses are essential for the finest and highest grade of die-stamping; in fact, a surprising range of work of the printed and embossed class is turned out by presses of this type.

Special printing inks are necessary for plate printing and die-stamping. The black ink ordinarily used for steel and copper plate printing is made to dry in the printing with a soft, velvety finish. The black and colored inks used for die-stamping dry with either a high gloss or velvet finish.

Rotary Intaglio Process. This process is an adaptation of the well-known photogravure method of engraving a plate mechanically, but the new method has many advantages, which have placed it in a class by itself. (Photogravure pictorial supplements for newspapers are now printed in two or more colors on tints by a new method.)

Although Rotary Intaglio is only about thirty years old, its advancement in the printing and publishing trades has been remarkable, and within the last few years has been developing with great rapidity. Among its principal advantages are the following:

Exceedingly beautiful reproductions can be made from original photographs, wash drawings, engraved portraits, or from any pictures having soft tone values. The printing from the engraved copper cylinders can be done on rough-finish stock, plain book paper, regular coated stock, or any other kind of paper without difficulty; on either or both sides of the paper, and in two different colors, all in one operation; and on various thicknesses of stock, from very thin paper to a medium thickness of cardboard. No make-ready on the press is required. No halftone, electrotypes or litho transfers are necessary. Reproductions can be made of all kinds of typographic matter, including text matter and forms of display composition, and these reproductions can be made in conjunction with those of the pictorial subjects.

Rotary gravure presses are built in sizes and styles to provide for a wide range of work. The new style intaglio newspaper press, for example, is capable of printing a complete 16-page supplement for a newspaper in one or two colors and at high speed. Presses of this same style are employed for printing illustrated magazine supplements, mail order catalogues and similar work. Several national magazines are produced completely by the gravure method. Nearly all of this work is printed in one color, sepia and photo-green being the two most popular.

In addition to the several makes of newspaper rotary presses which are now in use, there are several makes of sheet-fed rotary gravure presses, and with a machine of this type close register printing is possible, also multi-color printing from a series of engraved rolls. The supplement for at least one great newspaper is printed in multi-color by gravure, and one national magazine is produced by a combination of gravure and offset printing. Fine process color work by gravure is a possibility of the near future.

PLANOGRAPHIC PRINTING

Lithography. This term refers only to printing from stone, but is often erroneously applied to offset printing or planography. The art of lithography, discovered by Alois Senefelder, is a chemical process of printing from designs made with a greasy substance upon stone. The best stone for lithographic purposes is a kind of calcareous slate, found on the banks of the Danube, in Bavaria, although other grades of stone are being utilized with more or less success.

Stone lithography is admirably adapted to the reproduction of color pictorial work, as many as sixteen different colors and tints frequently being used in the printing of art pictures. Lithography is also used in printing letterheads, bonds, bank checks, certificates and other work in one color.

The lithographic artist works in three different ways in making the printing designs on stone: 1. The original design is first prepared on a small stone, and then by means of transfer paper is duplicated upon the large stone as many times as may be desired. 2. The original design is drawn with litho crayon directly upon the surface of the large stone. 3. The design is applied to a small stone, or to a metal plate, by means of the photo-lith process, and then transfers are made to the large stone.

The working principle of lithography is based on the simple fact that grease will not mix with water. The lithographic press is equipped with both water roller and inking rollers. When the press is in operation the water rollers first pass over the stone and dampen all parts of the design which are not to print. The inking rollers then pass over the stone and apply color only to the parts of the design which have not been affected by the water. The impression cylinder of the lithographic press is covered by a resilient rubber blanket. Printing is done from the flat surface of the chemically prepared stone, and when a sheet is printed no impression is visible on back of it.

A litho crayon is composed of beeswax, shellac, tallow, mastic, turpentine, soap and lampblack. Litho "tusche" or transfer ink contains much the same ingredients, with the grease a little more dominant.

Offset Printing. This term means planographic printing from a prepared metal plate on a rubber blanket which in turn *offsets* the impression on paper, tin, fabric or other material. The modern offset printing process is an evolution of a similar process used by tin decorators for many years past. By this comparatively new method it is possible to do practically all classes of work produced on stone lithographic presses; in truth, the offset process is rapidly supplanting stone lithography throughout the industry.

There are two different methods of offset printing: first, the "wet" method, which has a close relationship to regular lithography; second, the "dry" method, which dispenses with the use of water rollers. The "wet" method is the more practical for all purposes, but the "dry" method is developing to a surprising extent, and may eventually gain ascendancy.

Numerous makes and styles of offset presses are on the market, including direct offset, rotary offset, and platen offset presses. The sheet-fed rotary offset press is by far the most popular of all. The various makes of this style of machine all work on the same principle: the press has three cylinders which revolve in contact; the upper cylinder carries the curved printing plate, the middle one contains the rubber blanket, and the third cylinder carries the sheet to be printed. When the press is in operation the first cylinder prints on the rubber blanket cylinder, dot for dot and line for line, exactly the same as the detail of the etched plate. The impression is then perfectly transferred to the surface of the sheet of paper. By the offset process it is practicable to print on the cheaper, rough grades of stock to almost the same advantage as on smoothly-finished paper.

Rotary offset presses are built in various sizes, and in both single and two-color models. Prepared zinc and aluminum plates, ready for transfer work, are supplied by lithographers' supply houses, although some offset printers prefer doing their own graining and processing. Every metal plate must be grained and treated before printing designs are applied to it. A plate may be regrained and used over again a number of times.

During the last few years a number of photo-offset processes have been perfected, each of which possesses peculiar advantages of its own for certain lines of work. By means of some of these processes it is now possible to photograph a design directly upon the surface of a prepared metal plate, and then to mechanically etch the plate for printing. The artist may also draw a design directly upon the surface of a prepared plate, and transfers of pictures and type forms can be made upon a plate in the same manner as for stone lithography. Process color printing is being done by the offset process, the plates for the various colors being etched by a method much like that used in photo-engraving.

CHAPTER X

SOME CHEMICAL PROPERTIES OF PRINTING INK

(The Manufacturing Side)

OBSERVATIONS OF A PRACTICAL INK MAN

IT is an axiom of all trades that a workman should be familiar with his tools, and that of printing is no exception. Every printer should know the materials he uses, and of all materials entering into the production of good printing none is more important than the ink.

The manufacturing of printing inks, originally carried out by the printers themselves, gradually became so complicated and so specialized that it was absolutely necessary to separate it from that of printing in order to insure economical large-scale production and to permit careful study of the best and most economical methods of manufacture. The present-day methods used are the result of close co-operation between the printers and specialists who have devoted their lives to a study of the requirements of the printing industry. These requirements are so varied and complex that it is difficult to know where to begin to describe them. The most logical division of printing is into three general classes: letterpress from raised type, litho from flat surfaces, and intaglio and plate from an engraved or etched surface. The inks made for each of these processes differ considerably from one another.

Under the above headings also come inks that are used for many special purposes and which must withstand various substances and conditions that would prove disastrous to ordinary inks. Among these may be mentioned paraffin paper inks which must not bleed in hot paraffin, special label inks that will not be affected by alcohol or acids, soap-wrapper inks to withstand alkalies, poster and awning inks to withstand sun and weather, tin printing inks to withstand baking, rubber printing inks to withstand the vulcanization process, and non-poisonous inks for surgical dressings which must withstand the sterilization processes. The wide variation in the requirements is illustrated by the fact that the consistency of inks ranges from those fluid enough to be fed to the printing surface through wicks to those that are hard enough to be broken with a mallet, and can only be used on hot presses.

In view of these facts, it can well be realized that the life of a printing-ink maker is not a "bed of roses," and that one problem after another duly presents itself to be overcome. With this great diversity of requirements it might be interesting to know that about five hundred different raw materials are used by a modern manufacturer making a general line of inks.

Printing ink consists essentially of a pigment and a vehicle intimately mixed and thoroughly ground to a high degree of fineness. Printing inks are composed of some or all of the following: pigments, compounds, driers, dyes and vehicles. In the technical sense a pigment is a material insoluble in water or oil, which is suitable by reason of its softness to be used in the manufacture of printing ink. A dye, on the other hand, is a substance which is soluble either in oil or water or some other medium. A vehicle is any material which is used as a medium for carrying the pigment from the block or plate to the paper, and generally is an oil or oil varnish, but sometimes consists of water or a water varnish, for example, in the case of water photogravure inks.

Pigments may be divided into two general classes, the organic and the inorganic. The organic pigments are complex compounds of the hydro carbons, and the inorganic all other pigments. The organic pigments may again be divided into two subdivisions, those from natural dyes and those from coal tar dyes.

Pigments from the natural dyes were formerly very widely used but are of practically no importance today, being the least important of all the classes. They are dull and generally more expensive for a given strength than any of the other classes.

Pigments from the coal tar dyes form the second most important class. The dyes are derived from coal tar by distillation and other chemical processes, and the pigments made from these dyes by precipitation, generally with metallic salts, such as alum. The most brilliant colors belong to this class but also the most fugitive. Great advances are being made, however, in developing pigments that have a high degree of permanency, although this quality is usually in inverse proportion to the brightness.

The classification of coal tar dyes is generally quite complex, and is based on the chemical properties of certain groups always present in the molecules. In order to simplify this classification, it may be based on the three distillation fractions that are obtained from coal tar. The first fraction contains the single ring compounds, benzene, toluene and xylene. The single ring has reference to the molecular structure which is represented as a hexagon. The second fraction contains the double ring naphthalene and the third the triple ring anthracene. All coal tar dyes have one or more of these rings present in their molecule.

Natural earth colors rank third in importance and have a limited use in the manufacture of printing inks because of their hardness. At times they are indispensable, however, when cheap alkali proof or permanent inks are required.

The artificial inorganic colors are the most important of all. Three-fourths of all pigments now used in printing ink belong to this class.

Of these, the most important are the iron blues, chrome yellows, and chrome greens.

The iron blues are made by the reaction in aqueous acid solution of sodium or potassium ferrocyanide (yellow prussiate) and ferrous sulphate (copperas) in the presence of a suitable oxidizing agent. There are three grades—Bronze blue is distinguished by its metallic luster, Milori blue has a greenish undertone and Prussian blue a reddish undertone. They are all powerful colors that are permanent and acid proof after an initial change has taken place which tends to give them a greener hue. They are often used for toning black.

Chrome yellows are a very important class of pigments. They are precipitated in cold aqueous solution by the reaction between potassium bichromate, and either the normal or basic lead acetate. They vary in shade from lemon yellow to deep orange. The above reaction gives primarily the normal lead chromate which is a rich yellow of slightly orange hue. The lighter shades are produced by the formation of lead sulphate in varying amounts at the time of precipitation. The redder shades are produced by the addition of varying amounts of basic lead chromate, which is also precipitated simultaneously with the normal lead chromate by the addition of certain alkaline reagents which neutralize the acid naturally present in the solution. These colors are brilliant in tone, dense, opaque, strong and quite permanent. The latter is dependent upon atmospheric conditions as lead compounds will all darken on exposure to sulphur gases.

Chrome greens are mixtures of iron blues and chrome yellows made by striking one pigment upon the other in the same solution. By precipitating together quite a different result is obtained than by simply mixing the two colors made separately.

The above mentioned colors—blues, yellows and greens—are good natural driers when ground into varnish, and are quite fast to light but not alkali proof.

Ultramarine blue is made by heating together china clay, soda, sulphur and charcoal. These ingredients are thoroughly mixed, ground and carefully roasted, but the finished product has a crystalline tendency and works with difficulty. On account of the presence of sulphur, ultramarine inks should not be used on copper electrotypes. This also applies to vermilion, which is a sulphide of mercury of a brilliant scarlet tone. Vermilion occurs sometimes in nature, but is generally made artificially. It is very opaque and heavy. It is considered permanent to light, but strange to say, it turns dark with fading instead of lighter. It is expensive to print with, owing to its heavy specific gravity, which does not allow as many impressions to be obtained per pound as from other pigments of approximately the same shade.

Carbon black is most important of all pigments to the printing-ink maker. Blacks are referred to more in detail in another chapter, but among the blacks which consist principally of carbon there are many varieties. Carbon black is the name generally given to gas black made by burning natural gas with an insufficient supply of air.

Lampblack is made by burning oil, generally creosote or tar oil, in specially designed burners, with a minimum supply of air. Lampblack is more opaque than carbon black and gives flow to inks whereas gas black makes short buttery inks.

Bone black is made by charring bones and then grinding to the required degree of fineness. It is somewhat crystalline and rather heavy in specific gravity. Its use is confined generally to plate inks, and it has a very deep mass tone but is relatively weak. Vine black is made by charring vines and other vegetable matter, similar to the way bone black is prepared. Acetylene black is made from acetylene gas which is obtained by allowing water to drop on calcium carbide. It is a very expensive black, but is an excellent one. Its expense, however, precludes its use today.

What the general public calls a black ink is really a blue-black. An iron blue or aniline blue is almost invariably added to black printing inks.

Gold and silver bronzes are made by mixing and pulverizing metals such as aluminum, copper, brass and so forth, in stamp mills to the required degree of fineness. They are sometimes dyed with aniline colors, giving greens, violets and other shades of bronzes.

In matching, the choice of colors is very important. For example: To get a bright green, a greenish yellow and a greenish blue must be used; because an orange shade of yellow or a red shade of blue will give a "dirty" olive green. A good general rule is to pick out colors nearest in shade to the color one is trying to match. Complementary colors are the best to use to get an attractive design, for when these colors are used a pleasing result to the eye is obtained; for example, red and green are complementary colors and this combination goes well together.

Permanency is a relative term, used rather loosely when referring to colors. Since nothing will stand up indefinitely against heat and chemical reaction, we can see that there are very few pigments capable of being designated even as slightly permanent.

Permanency in colors generally has reference to their ability to withstand sunlight and ordinary atmospheric conditions. Carbon black leads all other pigments in this respect, the reason for this being that it is an extremely inert substance, unaffected by chemicals, such as acids, alkalies, and water, and practically sun proof.

Next in line come the earth pigments. These are not as inert as carbon black, being soluble in acids and therefore they show more effects from exposure. It is drawing too fine a line, however, to classify any of these as not permanent.

Among the artificial lakes or organic pigments, there is a wide variation in their ability to withstand sunlight and weather. Some fade noticeably within two hours, others will hold their color for a week and a few will not show much change after an exposure of two months. The alizarine colors are the best and for that reason. Madder lake which is an alizarine dry color is sometimes called 100 per cent permanent and other colors of this class graded accordingly after comparative tests.

Compounds and driers are used to counteract adverse conditions in the pressroom. They are essential ingredients, but indiscriminate use of unsuitable compounds makes a bad condition worse. For example, on a wet day even the best paper will absorb moisture, thereby affecting the binding property of the coating, and inks that print satisfactorily on a dry day will "pick" on a wet day, due to this reason.

Atmospheric conditions are beyond the control of the ink maker, and he should not be blamed for conditions over which he has no control. Some steps have been taken in America to standardize atmospheric conditions by means of manufactured air. In the carrier system the air is drawn into the pressroom by means of large fans and is passed through sprays of water and heating coils in order to obtain uniform humidity and temperature.

Inks dry in one or more of three ways: first, by absorption; second, by oxidation; and third, by evaporation. Some inks dry all three ways. Most inks dry two ways. Newspaper ink dries by absorption, and for this method of drying the paper should be soft and porous. Inks printed on coated, art, or bond paper generally dry by oxidation; that is, absorption of oxygen from the air. This absorption can be hastened by driers, but as a rule even the strongest drier will not dry an ink in less than four hours under ideal conditions. Only certain oils and varnishes will oxidize, and it is a waste of drier to put it in those which will not dry by oxidation. Intaglio inks dry by absorption and evaporation, and the speed of evaporation depends on the temperature of the atmosphere and vapor pressure of the solvents.

An increase of temperature hastens all forms of drying. The following figures taken from one great laboratory may be interesting: An ink which dried in 24 hours at 60 degrees, dried in 5 hours at 80 degrees, and skinned on the press in 4 hours at 90 degrees. Inks may set in a few seconds, but should not dry hard by oxidation in less than four hours. Humidity generally retards drying, and damp, cold days are the hardest in which to get quick drying. Certain paper retards drying, due to chemicals contained in it, and extra driers are needed. The porosity of paper also affects the drying, due to differences in absorption. Thin films naturally dry better than thick films.

There are two kinds of driers, viz., Japan driers, which evaporate, and paste driers, which do not. Japan driers are made by dissolving metallic salts of weak acids, such as resinites, acetates, tungstates, etc., in solvents, such as boiled oil and turpentine. Lead, manganese and cobalt are generally used. These salts act as catalysts and are carriers of oxygen, causing it to combine more easily with the oils and varnishes, and changing drying from a question of days to a question of hours only. Paste driers are like Japan driers, only more concentrated. They contain no turpentine or other solvents, and are of a short buttery body, especially adapted for litho work. Driers are sometimes added in the dry form and ground into an ink as are the pigments.

Non-driers are various ingredients added to eliminate trouble in presswork. For example, beeswax reduces tack or stickiness, retards drying slightly, and shortens the ink. It can be used in litho work and is the best material to use, but rather expensive. It has a tendency to dull the ink and to make it look grainy, as though it were not ground, but this appearance causes no trouble in running. Soap lubricates an ink, and reduces tack likewise. It has a tendency to shorten the ink and to give a clean and sharp impression. It prevents clogging of the type, and aids distribution, but retards drying slightly. Some soaps are dangerous to use, owing to the free alkali contained in them, and care should be exercised to choose the proper soap. Lard, tallow, petroleum jelly and vaseline should be used very cautiously, as they retard drying very much. They also reduce tack quickly.

Printing ink vehicles are probably the most important constituents of a printing ink. They may be placed into two divisions—oils and varnishes.

Oils may be divided, according to their source, into three divisions—mineral, animal and vegetable. Mineral oils are obtained from the crude oils from wells, and are of two general classes, those of paraffin base and those of asphaltic base. These are refined into a series of products, ranging from very thin materials, like petrol, to wax from the paraffin base oils, or tar from the asphaltic base oils. All of these products are used somewhat in printing inks, especially in the cheaper grades. They aid lubrication, but should not be added to inks indiscriminately, as they will not dry by oxidation, only by evaporation or absorption, and are especially dangerous where bond paper or hard-surfaced paper is used. Fish oils are very seldom used, but their future use will probably be more extended as processes are worked out for their deodorization. These oils are very hydroscopic, becoming sticky in damp weather. Lard oil and neat's-foot oil are occasionally used for inks for duplicating machines, stamp pads, etc., where drying must not take place. They will not oxidize, and are considered non-drying oils, like mineral oils. Linseed oil is the most widely used oil for medium and better grade inks. It is made from flax-seed, which is grown in various parts of the world.

In America the printing ink varnishes are graded from No. 0000 which is the thinnest to No. 8 which is the heaviest. In England they are called tint, thin, mid, strong, extra strong, double extra strong, the last being the heaviest. These are made by heating the oil to between 550 and 620 degrees F. During the boiling process the fumes arising from the kettle are sometimes set on fire in order to make burnt varnishes and plate oils. These are not so greasy, and are somewhat shorter than the boiled varnishes. All linseed varnishes dry excellently by oxidation, and acidity varies from one-half to 10 per cent. The lower the acidity, the better and cleaner the varnishes. Soya bean oil, sometimes used as an adulterant to linseed oil, is not so good a drier as linseed. Cottonseed oil is considered a non-drying oil. Rosin oil has a characteristic odor, will oxidize, but not as readily as linseed, and is used extensively for the cheaper grades of black. China wood oil, sometimes called tung oil, is a very powerful drying oil, even more so than linseed. It is used very little owing to its high price. Varnishes, in the more common usage of this term, are made from the oils described by melting resins in them.

The dyes used in the manufacture of printing inks may be either oil or water soluble. Oil soluble dyes generally bleed in alcohol. They are used in toners for blacks and duplex inks. In duplex inks a mixture of pigment and dye is incorporated in the varnish, the dot carries the pigment, and the oil spreads around it, which gives the two-toned effect, and may be described as an island of one color in a sea of another. These are rather uncertain inks, and the paper, temperature and rate of drying all affect the shade. They should dry slowly in order to spread properly, and a good match cannot be determined until 24 hours after printing. Water dyes are very little used in printing ink, but have some application in making copying inks, ruling inks, and sensitive check inks.

It will be seen, therefore, that the physical and chemical properties of an enormous number of materials must be known to the manufacturer of printing inks, who must blend these in the proper proportion to obtain the best results. After the proper choice of raw materials has been made, there still remains the proper mixing and grinding. After grinding the proper number of runs through the mill, which vary from two to twenty, the ink should be cooled and carefully compared with a standard sample representing the previous lot furnished to the printer.

While on the subject of testing, it may be well to state that the best service a manufacturer of printing ink can give the printer is to keep his inks uniform and the most progressive manufacturers today carefully control every ounce of raw material entering their plants by tests for its uniformity before it goes into their stock to be made up into ink. The finished product is also carefully tested, especial attention being given to the color strength, overtone and undertone effects, consistency and setting qualities and when time allows, the drying. This means that a complete set of standard samples must be kept of every raw material used and of every finished ink manufactured, and an elaborate and well-equipped testing department must be maintained.

Ink is the most important material in the printed job, no matter how good the paper, presswork, printing plates, etc., may be. Printing ink is really a "prescription" compounded by the ink maker, who prescribes the formula dependent on the color strength desirable, character of printing and the press which will use it, the kind of stock it is to be used upon, as well as atmospheric conditions attending the printing process. An ink manufacturer diagnoses printing ills, prescribes for them, and makes the medicine. He is in essence a personal service merchant rather than a dealer in commodities. These facts have been mentioned briefly to demonstrate that the ink-making business is not and never will be anything else than a personal service business, and not one of competitive commodity prices. A saving is accomplished only when a cheaper ink per pound will do exactly what the more expensive ink per pound will do. A more expensive ink, using the same class of color as a cheaper ink, is more concentrated. That is, the color strength is greater, which means that the ink has not been reduced with some cheap form of white pigment in order to lower the cost. Consequently a thinner film is required to get a good impression, which fact decreases the chances of offsetting and reduces the delay in the pressroom caused by this and other troubles.

CHAPTER XI

OILS, VARNISHES, DRIERS APPLIED TO THE MANUFACTURE OF PRINTING INKS

WHAT race or nation is to be credited with first mixing oil and carbon in the preparation of ink is still a controversial question. Some historians attribute this to the ancient Egyptians, others to the Chinese. The recent opening of tombs in Egypt has drawn renewed attention to the fact that the characters on the papyrus and the hieroglyphs of 3,000 or 4,000 years ago are apparently as black today as when written or drawn. That a carbonaceous black made from the bones of animals was used is proven beyond a doubt, and the permanency of materials entering into the composition of ink has probably never been excelled in any subsequent period of history. Since carbon (though made from different sources) is the pigment used in all black inks today, the question is, did they really mix oil with the carbon? The colors on the sarcophagi and decorations on the furniture are held on by a medium other than a gum. Though the black ink can be washed from the papyri with water, still after so many years of oxidization even an oil ink might be washed from a surface like that of the papyrus leaf.

Dioscorides, personal physician to Antony and Cleopatra, leaves a record of the best proportions of oil and lampblack to be used in the making of ink, but unfortunately he does not specify the kind of oil used. Flaxseed or linseed oil was known to the Egyptians, and flax in boll, or seed, is mentioned in Exodus IX, 31. The Egyptians were large growers of flax from which they made the beautiful linen fabrics preserved to our time. The oil was extracted by steeping flax-seed in hot water and skimming the oil from the surface. It may thus have been flax-seed or linseed oil that the Egyptians mixed with lampblack carbon to make their permanent ink and paint.

Linseed oil was doubtless the earliest known of the oxidizing oils which when exposed in a thin film would produce a skin insoluble in water and practically permanent. It is this property of linseed oil discovered so many years ago which makes its history down through the ages most interesting to the printer.

The property of boiled linseed oil to dry hard quickly and not penetrate through the paper, or spread sidewise, is what makes it so extremely valuable in good printing ink. Since the invention of printing, every newly discovered oil has been tested as a substitute for linseed oil; although steel engraving inks now contain efficient oils other than linseed, no suitable substitute has been found for it in modern lithographic printing inks. Evidence of the incorrect use of raw or unsuitable oil is found in many old printed books where a yellow stain in the paper surrounds the type, which would not have occurred had properly boiled linseed oil been used in making the printing ink. Plate printers customarily made their own intaglio printing inks by mixing lampblack with an oil other than linseed, especially when the latter was not "short" enough or too "tacky" as they term it, and this accounts for the yellow stain so frequently found in old copper and steel plate prints.

The Chinese are credited with many ancient discoveries, but oil ink is apparently not properly one of them. They have used water ink from earliest times, and still do, though some oil printing ink is now used on modern printing presses. Painters also mixed their colors in water. Tempera or fresco painters mixed colors with the finishing coat of plaster or mortar applied to the walls and this gave the colors their permanency, they lasting as long as the walls. Sometimes a linen cloth was glued on the wall, and on this canvas they laid their colors mixed in water, to which was added as a binding medium the yolk and white of egg beaten together, or a gum, having added to it at times, wine, vinegar, oxgall or other ingredients, the mordants used being guarded as secret by each individual painter.

This was the state of the art of painting until 1500 when certain Italian painters began mixing oil with their colors. Other historians attribute the mixing first of oil with paints to John and Hubert Van Eyck of Bruges, who founded the Flemish school of painting. By one of those coincidences that frequently occur in history, printers and painters began about the same time to mix oil with their pigments. The invention of movable type came about the middle of the fifteenth century and it was in the early part of that illustrious century that the artist painters began the use of oil instead of water and gum as the media to secure their colors onto surfaces. Mr. Theodore L. De Vinne in his *The Invention of Printing,* after much research on the subject says:

"There is no trustworthy account of the invention of printing ink, but the types and ink were undoubtedly invented together. One was the proper complement of the other. It may be supposed that Gutenberg acquired the knowledge of the newly found properties of boiled linseed oil from the German painters. It is certain that he used oil as the basis of his ink, and that it was also used by his pupils and his successors. And it has been in use ever since, for there is no substitute.

"We have not been told how this ink was compounded. Our nearest approach to this knowledge is through the cost book of the Ripoli Press for 1481, which specifies and prices the materials. Here follow the ingredients of Printing Ink used by the Ripoli Press:

Ingredients for Ink Making	Tuscan Currency	U. S. Currency 1876
Linseed oil, barrel..........	Lire 3 10 0	$3.17
Turpentine, pound.........	4 0	.18
Pitch, Greek..............	4 0	.18
Pitch, black...............	1 0	.04½
Marcassite	3 0	.13½
Vermilion	5 0	.22¾
Rosin	3 0	.13½
Varnish, hard	8 0	.36
Varnish, liquid	12 0	.54
Nutgalls	4 0	.18
Vitriol	4 0	.18
Shellac	3 0	.13½

"As no mention is made of smoke black, we have to infer that pitch was burnt to make this black. Linseed oil, as the most bulky ingredient, very properly occupies the first place. The real value of nutgalls and vitriol is not so apparent; they were important ingredients in writing ink, and the Italian printer may have thought them indispensable in printing ink. Shellac and liquid varnish were used to give a glossy surface."

Ink-making being an exceptionally dirty business, it was left to apprentices and workmen of meagre intelligence, with the result that workable ink was the exception. The risk of fire through boiling linseed oil was another reason why it ceased to be undertaken by printers and became

KETTLES FOR "BODYING" VARNISH

a distinct and separate trade. In the competition that followed, the quality deteriorated to the extent that one historian, Moxon, in his *Mechanick Exercises,* 1683, said of printing ink in his time (Moxon compares the printing ink made in England with that made in Holland and gives reasons why the Dutch ink is superior. His criticism is worth quoting as it holds good for all time):

"Our inck-makers to save charges, mingle many times Trane-Oyl (whale-oil) among theirs and a great deal of Rosin; which Trayne-oyl by its grossness Furs and Choaks up a Form, and by its fatness hinders the Inck from drying; so that when the work comes to the Binders, it Sets-off; and besides is dull, smeary and unpleasant to the eye. And the Rosin, if too great a quantity be put in, and the form be not very lean-beaten, makes the Inck turn yellow: And the same does the New Linseed-oyl.

"Secondly. They seldom Boyl or Burn it to that consistence the Hollanders do, because they not only save labor and Fewel, but have a greater weight of Inck out of the same quantity of Oyl when less Burnt away than when more Burnt away; which want of Burning makes the Inck also, though made of good old Linseed-oyl, Fat and Smeary, and hinders its Drying; so that when it comes to the Binders it also Sets-off.

"Thirdly. They do not use that way of clearing their Inck the Hollanders do, or indeed any other way than neer Burning it, whereby the Inck remains more Oyly and Greasie than if it were well clarified.

"Fourthly. They, to save the Press-man the labour of Rubbing the Blacking into Varnish on the Inck-Block, Boyl the Blacking in the Varnish, or at least put the Blacking in whilst the Varnish is yet Boyling-hot, which so Burns and Rubifies the Blacking, that it loses much of its brisk and vivid black complection.

"Fifthly. Because Blacking is dear, and adds little to the weight of the Inck, they stint themselves to a quantity which they exceed not; so that some times the Inck proves so unsufferable Pale, that the Press-man is forced to Rub in more Blacking on the block; yet this he is so often loth to do, that he will rather hazard the Content the Colour shall give, than take the pains to amend it: satisfying himself that he can lay the blame on the Inck-maker."

Putting the blame on the ink maker has, since the invention of printing, been the favorite pressroom badinage. William Savage in 1832 blamed everyone but himself for badly made printing ink. This is found in his book entitled *Preparation of Printing Ink both Black and Colored.* He comments: The process of making printing inks has never before been treated by a practical man. Having been an ink maker and printer for 23 years, he does not think possible that ink would work cleaner or more freely, produce finer impressions and retain the freshness of color without imparting stain to the paper, than the inks, both black and colored, for which he gives the recipes in this work. A strange thing about it all is that the excellent ink used in printing it was not made according to any of his recipes. If Savage could see the present-day requirements of ink, the textures on which it is used, the speed of the presses, etc., he would realize how limited and unpractical was his knowledge on the subject.

King George III of England did much toward the improvement of printing ink and in a most unexpected way. His Act for the suppression of seditious societies compelled every printer to affix his name and address to whatever he printed, which automatically stimulated rivalry among printers as to the legibility and beauty of their type, and this required better inks. It was the magnificent edition of Shakespeare's works printed by William Bulmer, the first number of which appeared in January, 1794, that did most to encourage art in ink-making in England. At that time excellent ink appeared in the printing of Bodoni at Parma and Didot of Paris. Bulmer in his Shakespeare strove to excel even the art of these printers.

One often hears the comment that ink used by Gutenberg and printers of incunabula was blacker than the printing ink of today. This is not the case. The ink in the Bibles of Gutenberg, for instance, appears black, but that is due to the type used being larger, with an exceedingly heavy face, without hair lines. Should the pasty ink they used be applied to the delicate lines in present-day type, the impression would scarcely be readable. The type used in Bulmer's Shakespeare was cut by William Martin, formerly with Baskerville. It had the fine hair lines and sharp serifs of the Italian and French printers and hence required the finest and blackest printing ink possible. That such an ink was made for it is evident from the superb sharpness and blackness of the type, which endures as a lasting monument to Bulmer, though the master who compounded the ink will remain forever unknown.

From Savage we learn that many of the early ink makers added spirits of wine in compounding their inks. This was of no advantage to the ink, though some ink makers and pressmen were accused of making personal use of the spirits. Fertens, a French painter, described his method of giving brilliancy to ink. He steeped a small piece of isinglass in brandy for 24 hours and added this to the ink. Another ink maker used this idea to absorb any grease or fat from the linseed oil: "The instant your oil becomes hot, throw into it a pound weight of dry crusts of bread and a dozen onions. These things absorb the grease of the oil." The use of soap in ink was kept a profound secret until Savage told how it kept the ink from clogging on the face of the type. Though printing ink with soap in it adheres to the face of the type, it leaves the type clean and attaches itself to damp paper. He concludes that "without soap, good printing is impossible." Today we know that this is a fallacy.

Savage recommended to printers the following as the best formula for a reliable black ink: "Balsam of Copaiva (copaiba) 9 oz., lampblack 3 oz., Indigo, or Prussian Blue, 1¼ oz., Indian-red ¾ oz., and turpentine soap 3 oz. The whole to be ground on a stone to impalpable fineness, when it will be fit for use." The objectionable smell of the balsam of copaiba was to be overcome by the addition of three or four drops of creosote,—questionable taste, to kill one disagreeable odor with another, but it is done even in modern times.

In our own country, before the Revolutionary War, printing ink was imported from England and Holland. It is said that Rogers & Fowle of Boston, 1742 to 1750, made good ink, and Benjamin Franklin was making more ink in Philadelphia than he could use in his own business, as he advertised it for sale. During the Revolutionary War printers were in sore straits for printing ink and from force of circumstances learned to make it for their own use. Many were the oils they tried in their inks. Flax was cultivated then only for its fibre; the seed was waste. Now flax is grown for the seed. How the industry grew is evidenced by the fact that in 1860, though we made one million gallons of linseed oil, we were obliged to import six million gallons. By 1891, we had grown more than sufficient to supply our needs, which then permitted exports to other countries.

During the World War the scarcity of flax-seed and its high price induced many farmers to include flax among their crops. Since then the growth of flax has increased and the methods of pressing the oil from the seed have become more and more economical, so that now linseed oil production has become an industry of vast importance in this country. Most flax-seed comes from the Northwestern states,—Minnesota, Dakota, Idaho, Montana, Oregon and Washington, though some comes from Kansas and Nebraska. We import flax-seed from Argentina and Uruguay, as well as considerable from Canada. Flax grows to a height of 20 to 40 inches. From a bushel of seed about three gallons of oil can be extracted. Unfortunately flax so impoverishes the soil that land on which it is grown becomes what is called "flax sick," and crops must be rotated until the soil recovers from this "sickness." Laws in many states forbid the adulteration of linseed oil. If adulterated, it must be so marked and the purchaser notified.

Many substitutes for linseed oil have been found, particularly for use in news inks. The use of rosin oil was first proposed by Pratt of New York in 1848. He used rosin oil, 20 parts, rosin 8, and yellow soap, melted together, and in this the lampblack was incorporated. Sam Turner of Brooklyn patented in 1853 the use of colophonic tar in the making of printing ink. In 1855 Caleb Thompson of Michigan received a patent on the use of 4 pounds of litharge and 2 pounds of acetate of lead to

40 gallons of linseed oil. This began the use of chemical driers in linseed oil, which has been the subject of ceaseless experiment among printing-ink manufacturers ever since that time.

The Civil War, through the increased demand for newspapers, brought about further changes in the ink oils and driers used. The use of rosin and its derivatives increased, which, together with paraffin, coal tar and soap, have been with black the chief ingredients in news ink up to 1865. George Duryee of New York discovered that the tar residuum resulting from the distillation of petroleum could be used in newspaper ink, so that for a time considerable of this was used for that purpose. However, newspaper ink of today, to conform to needs of press and paper, must be free from the brown stain which is always present where asphaltic products are used.

The oil which most nearly conforms to this need is a clear-toned mineral oil made from the distillation of crude oil, and this is now the principal ingredient in modern newspaper ink. It is in general the last fraction in the distillation of the crude, the fractions being—first, gasoline; second, fuel oil; third, ink oil, leaving behind a residuum comparable to native asphalt.

The patents issued in all countries on oils, driers and compounds for use in printing inks are very numerous and date back for more than half a century. Still for many processes of printing, such as lithography and engraving and bank-note printing, as said before, no efficient substitute for linseed oil has been found. The treatment of linseed oil to make it dry quicker has been the subject of a large number of patents. It has been charged with oxygen and even with ozone until the oil was changed into a composition that could almost be used as a substitute for india rubber. Siccatives of various kinds are still being experimented with in printing inks. These driers, as they are called, are usually metallic salts that absorb oxygen readily. It must be remembered that should the ink dry too quickly, it will set on the forms and rollers, and should it dry too slowly, it will offset. How to judge the proper quantity of drier in ink to work equally well with all pigments and oils in variable climates and temperatures, is the vexatious problem in the chemical laboratories of all ink manufacturers today, and perhaps always will be.

The action of the different metallic salts of lead, manganese, cobalt or other driers is supposed to be this: These chemicals are intermediaries that take up the oxygen from the air and give it to the linseed, or other oil, which becomes oxidized more rapidly by their use. Salts of lead, manganese, cobalt, vanadium and other metals are now the basis of almost all driers in the market. These may come in powder, paste or liquid form. Their proper use could be discussed to the extent of a good sized volume, so cannot be extended here. The paper, press speed, purpose of the printing and climate are but a few of the factors entering into the problem, therefore the kind and amount of drier should be prescribed by the ink doctor.

Tung oil, as a promising substitute for linseed oil in the making of printing inks, is attracting much attention just now. It has good drying properties, and by the introduction of modern machinery may be produced more cheaply than linseed oil. The Chinese name for this oil is "Tung-yu-shu." It is also called "China wood oil," possibly because the Chinese use it to saturate the wood with which their boats are built to render them waterproof. The oil is extracted from the seeds of a nut, about the size of a small orange, that grows on a tree indigenous to those parts. When these seeds are cold-pressed, they yield a pale oil, and when hot-pressed, the oil yield is greater though darker in color.

Tung may have the advantage of oxidizing quicker than linseed oil and it may become cheaper in price; still it has numerous disadvantages, among them being its disagreeable odor, which has thus far not been overcome. Further, tung oil dries with a mat surface similar in appearance to ground glass, and this, of course, injures the brilliancy of the pigments mixed in it. Besides all this, it is poisonous. Chemists are giving much study to tung oil and so hopeful are they of overcoming the present objections to it, that tung trees are being cultivated in the Southern states. In printing inks used for special purposes, where the noxious odor is not objectionable, tung oil has already been found valuable.

The Japanese use in printing inks a drying oil made from the seeds of the perilla plant, which grows in Japan, China and parts of India. In Manchuria, perilla oil is used in food. The seed yields 45 per cent of a pale yellow oil which is a good drying oil, though it tends to streak in drying. Other vegetable drying oils experimented with as substitutes for linseed oil are in part: hemp seed, an accidental adulterant of linseed oil, from Russia; Para rubber-seed oil; Niger seed, from Africa; the oil from the soya bean; poppy seed, from Mexico; our own sunflower seed; cotton seed; tobacco seed; and the oil from walnuts. All have been tried and still linseed oil remains without a rival as the oldest and most reliable medium in the making of printing inks.

CHAPTER XII

BLACK PIGMENTS FOR PRINTING INK

THE black pigments used in the manufacture of printing inks have not changed to any great extent since the earliest records of history. The Egyptians, painting on their mummy cloths or cases, used lampblack, as did also the Chinese and Hindus before them in the making of their writing inks, which have been known from time immemorial as "Chinese" or "India" inks.

Before attempting to explain how lampblack is incorporated with a vehicle, or oil varnish, to permit of it being used to give an impression, or print, it is advisable to define what constitutes lampblack. As it is often difficult to tell where the mineral kingdom ends and where the vegetable kingdom begins, or to determine the division between the vegetable and the animal kingdoms, so is it difficult to properly define what constitutes true lampblack. Moreover, it is hard to differentiate it from other blacks to which it is closely related.

Lampblack, as its name signifies, was originally made by collecting the smoke from a lamp. Unquestionably, this was how lampblack was made by the Chinese and Egyptians. What was burnt in these lamps to give a flame was in all probability a vegetable or mineral oil, or some resinous material rich in carbon. The Egyptians certainly had the knowledge of obtaining oils from mineral products, and that they used bitumen extensively in the embalming of their dead is proven by the coating of their mummy cloths.

Lampblack, therefore, to be genuine lampblack and suitable for printing ink, must be a smoke precipitation and must contain no charcoal or coke.

There is a characteristic and distinct difference between the smoke of a burning product, and the charcoal or coke of the same product. All material that is rich in carbon gives up its volatile matter when burnt in a closed retort, and the residuum left is charcoal or coke. We speak of the charcoal of wood, of bones, of leather and of rice hulls. We speak of the coke of coal. When wood or bone is charred the charcoal may properly be described as the skeleton of the wood or bone from which the volatile matter has been expelled, and in fact it is the skeleton, for it retains the frame-work, the grain and the structure of the wood or bone from which it was derived. Under the microscope it is possible to determine the difference between the charcoal of different woods, for all of these different charcoals have distinct characteristics. For instance: that of willow is the softest of the charcoals, while that made from oak is hard and harsh. Charcoals of wood, bone, ivory, etc., are all black when burnt in a closed retort, but one and all of them retain the grain and structure of wood, bone or ivory, in just the same manner as the coke from coal is the skeleton of the coal.

The dissimilarity in the charcoals of the different woods was exemplified during the World War in the production of carbon for gas masks, when some of our ablest chemists were employed to solve the different problems regarding the absorption powers of the various charcoals. The United States Government imported large quantities of cocoanut shells for the express purpose of making charcoal from these shells, to be used in gas masks, it having been demonstrated that the charcoal of cocoanut shells and of peach pits had greater absorption power than the charcoals of various other woods.

The volatile matter expelled in the charring of these different products is a gas similar to illuminating gas made from coal, and by burning this gas and collecting the soot a true lampblack can be made.

There are many black pigments which are used in the arts and manufactures, and it is well to enumerate these:

Bone and ivory blacks, which are charcoals, are used extensively for steel and copper engraving inks and also in paints. They contain approximately 16 to 20 per cent carbon.

The so-called Frankfort and vine blacks were originally made from the tendrils of the grape vine, and from the sediments of wine vats. These blacks are also charcoals, although of a finer quality than those obtained from the burning of wood. These blacks cannot be used in the manufacture of printing inks, but are used extensively in the manufacture of engraving inks and are known as "soft blacks," in contradistinction to those made from bone or ivory, which are termed "hard blacks." The hard black gives a sharpness to an engraving, and is especially adapted for engraving line work, and what is technically known as counter work, while the soft engraving blacks are adapted to vignettes. Frankfort or vine blacks, as made in the United States today, are mostly made from wood pulp black, which is a material obtained as a by-product in the manufacture of paper. These blacks are similar to those originally made in Germany.

There is also Swedish black, which comes close to being a real lampblack. It is made from the bark of silver birch, which is packed in retorts, and is charred with an insufficient quantity of air to admit of complete combustion. The result is a mixture of charcoal and lampblack. The charcoal is derived from the cellulose material in the bark, so that in Swedish black we have a pseudo lampblack, which might be called the link between charcoals or coke blacks and true lampblack. This black is not used in printing ink.

True lampblack, being smoke, and containing no charcoal, is a superior and different product. It is a purer form of carbon than any charcoal, and is in a finer state of subdivision; it does not retain any grain or structure; it is amorphous; and it will be readily understood that it matters not how carefully the charcoal of wood, bone, ivory or any other substance is ground, it cannot have the fineness and flocculency of a smoke black. The very finest of the Frankfort, or charcoal blacks, even when ground, levigated, washed and floated, still retain the granular structure in the charcoal of the material from which it originated. It is this coke which makes these blacks unfitted for use in modern printing inks.

No charcoal blacks are suited for the use of printing ink, for the reason that they are not in a sufficiently finely divided state, and in consequence will fill up the type and the detail of printing plates. Nor will they have any elasticity when mixed in oils or varnishes, and thus would thicken up and not readily run down the fountain of a press, or distribute quickly or uniformly on the inking rollers.

The foregoing should give the reader an understanding of what constitutes true lampblack, yet something else is to be considered. Everyone knows that smoke may be readily produced from a flame, but few know that it may be produced apparently by means which are diametrically different. If we supply a flame with barely sufficient air to support combustion, the flame gives off smoke. This may be observed by taking an ordinary lamp and partially closing the top of the chimney. The flame at once begins to smoke, and lampblack collects on the inside of the chimney. The flame has been starved and there has been an interference of the draft for the escape of the dioxide of carbon from the flame.

Take the same lamp; introduce cold air, or allow a draft of air to strike the flame, and in the same manner as in the former experiment, smoke is deposited. If a saucer is held over the gas flame, smoke, or lampblack, is deposited. This is due to depriving the flame of part of its heat, which does not permit of its consuming the carbon, and it is therefore deposited as lampblack upon the saucer. This last-described method was probably the primitive one by which lampblack was originally made by the Chinese and Egyptians—viz., by allowing the flame of a lamp to impinge on some surface upon which the black was deposited.

The generic term for printing would include engraving, and printing on fabrics, and as has been mentioned, the char of bone, wood, and so forth, is better adapted for steel and copper plate engraving than lampblack, as are also the Frankfort and vine blacks for printing on calicoes and similar fabrics.

What then is the definition of lampblack for the use of the printing-ink manufacturer?

Lampblack must of necessity be smoke. It must contain no charcoal or coke. It must be a pure form of carbon. Lampblacks are now made which contain 2/100 of

1 per cent ash, and if such lampblack is put into a porcelain crucible and burnt out in a muffle oven, there would be practically no ash left.

It being a smoke, the particles forming the carbon are termed amorphous, and are in an exceedingly fine state of division. It is the fineness of the particles which gives the black its great staining and covering power and makes it peculiarly adapted to the purpose of printing ink manufacture, because when it is mixed with linseed oil, or resin oil varnish (the vehicles used for bringing the black onto the paper and making it adhere thereto), the black, due to its fine subdivision, is opaque. There are no interstices between the particles which would allow the light from the paper to pass to the eye. It makes a dense black impression on the paper.

Lampblack may contain a small percentage of oil and still be lampblack, but pure lampblack should contain no oil, and traces of it are often removed after the lampblack is made, by calcination.

It must not be supposed from these facts that the carbon collected from oil or gas must of necessity be lampblack. If oil or gas is passed through a heated tube or retort, the gas or oil is decomposed and carbon is deposited. This, however, is not a lampblack; it is an allotropic form of carbon, of a structure heavy and dense, and of a graphitic nature. It would have to be milled to a fine powder before it could be used even as paint pigment, and it would be entirely unsuitable for the manufacture of printing inks.

Some chemists have been led astray in regard to the manufacture of lampblack, believing that so long as the carbon contained in oil or gas was obtained from these bodies by dissociation of the constituents forming the hydro-carbon, lampblack was thus made. Nevertheless, this is not true.

Lampblack is carbon of a particular and peculiar kind, for the particles forming the black must have been in a state of incandescence in the flame, and it is only by the collection of such particles—flocculent, light, and in an extremely finely divided state—that lampblack is obtained. Lampblack is not, therefore, merely a product made from oil or gas, but must be made from these products in such a manner that this finely divided flocculent powder is produced. This can be best explained by the following experiment:

When a piece of metal or china is held over the flame of a candle, oil or gas, lampblack will collect on the depositing surface by allowing the flame to impinge. These black particles which are deposited have been in a state of incandescence in the flame, and would have been burnt up by the heat generated, had the temperature of the flame not been lowered by contact with the metal or china plate. The deposited lampblack, however, must be removed within approximately thirty minutes after the action of the flame,—otherwise the continued heat will change the deposit upon the collecting surface, from what would be a flocculent and amorphous form of carbon to an allotropic and hard carbon.

Having acquainted the reader with what constitutes a lampblack to be used for the manufacture of printing inks, we shall now try to explain how the different lampblacks are made, and the manner in which they may be tested for purity of color, coloring properties, etc.

The industry of making lampblack, until the discovery of printing, was undoubtedly of the crudest character, but with the invention of printing, as with also the manufacture of paints for covering wood, metal and other materials came a demand for improved methods of manufacturing lampblack.

The first improvement in this way was accomplished by erecting brick or stone cylindrical buildings, the roof of which was usually made of iron, cone-shaped, and fitted close to the inside of the circumference of the building, the roof being so adjusted that it could be raised or lowered. The oil, resin or material rich in hydrocarbons, was placed in a pot or pots in the cylindrical-shaped building, and heated until it gave off a gaseous vapor, which was then set on fire. A sufficient quantity of air was admitted through apertures at the bottom of the building to permit of combustion. When all the resin or oil had been consumed, the roof was slowly lowered, which in its descent scraped off the lampblack deposited upon the side of the walls.

The finer grades of lampblack were made by constructing a series of small chambers, hoods or bonnets, opening into each other, with a furnace at one end in which resin or oil was burnt. At the other end was a chimney which created a draft. The smoke passed from chamber to chamber, the heaviest particles depositing in the first of the series and the finest particles in the last. In this way lampblack or soot was graded. This crude method of manufacture was that used both in Europe and in the United States until about the year 1850.

In England, France and Germany, the principal raw materials used were tar oils, lard oils and resins. In the United States a considerable quantity of black was made from fish oils, and this manufacture was carried on in Massachusetts, most of the works being located on Cape Cod, and up until about 1880 there were a number of these small works, the black manufactured there being known as Cape Cod Black.

There was a considerable quantity of black made in the United States from resin, and resin dross, and the first works of any importance were erected in Baltimore and Cincinnati for the manufacture of what was known as Resin Lamp Black. This same kind of black was also made in Troy and Watertown, N. Y.

Blacks made from fish oil and resin contained a large percentage of impurities, and it was necessary that these blacks should be calcined to make them suitable for the manufacture of printing inks.

It was not until the production of coal tar oils, or what was designated in the trade as "dead," or creosote oil, that any distinct improvement in the method of making lampblack was brought about. It was not practicable to melt materials like resin and naphthaline so as to get them to flow readily through pipes, or even to burn these products in bowls or pans (placed in furnaces) to prevent the carrying over of a certain amount of free oil and impurities into the black. But, by the use of tar oils, it was possible to burn in a different way, and a vast improvement was made in the process of producing and collecting the lampblack from tar oil.

The buildings now used for this purpose, both in Europe and in the United States, consist of a brick or stone structure, having at one end a number of furnaces especially constructed for the purpose. These furnaces are connected by large pipes or openings into a series of condensing chambers communicating one with the other. Air is admitted through openings or vents into the furnace, in order that the quantity of air may be regulated to the amount of oil burnt, these vents being in the form of registers which can be regulated during the process of the burning of the oil.

In the United States both tar oils and petroleum oils are employed. The oil is conducted through pipes leading into the furnaces, each furnace having a separate supply pipe. The oil passing through these pipes drops upon pans or plates heated to a temperature sufficient to ignite the oil. The smoke is liberated from the flame and passes through the openings into the condensing chambers in which the black falls by gravitation, the deposit in the last of the chambers and that farthest from the furnace and nearest the chimney being the finest, and therefore, the best quality lampblack.

This modern method of making oil lampblack has many advantages over the old methods, for not only can the quantity of air adequate to maintain combustion be regulated, but the stream of oil which drops on the pans or plates is under control of the workman operating the furnace. This method also permits of the smoke being taken away immediately from the flame, and thus prevents the black from being reburnt, which was one of the great disadvantages in the older process. (It will be understood that the lampblack, to prevent loss of color, must be quickly removed from the flame.)

The grading of the different qualities of lampblack is not altogether obtained by the depositing of the particles by gravitation as described. The finer grades of black are often made by allowing the oil to flow slowly into the furnace, and having the oil drop on small plates or specially constructed pans, which permits less oil being burnt in the furnace. Identically the same oil may be burnt, to make quantity or quality of lampblack, by burning either rapidly or slowly. The method of burning the oil, the supply of air, the shape of the pan upon which the oil drops, as also the construction of the furnace and the manner in which the black product is drawn from the furnace to the condensing chambers—all have a relative bearing on the quality of the lampblack produced.

The quality of the oil, and the kind of oil, are also important factors. Generally speaking, it may be considered that the lighter the oil the finer the black; naphtha, gasoline and kerosene make finer grades of black than that made from heavy oils. The heavier coal tar oils are more economical, and as a rule give a larger yield of black per gallon, but they produce an inferior quality of black.

To summarize: In making the finest grade of oil lampblack, oils of light gravity are employed, and the oil must be burnt slowly in small furnaces which should be kept cool. (There are many methods now in use by which the furnaces are kept cool, by means of water, air, etc.) The draft or suction should be so arranged that the black as it comes from the flame does not hover or hang in the furnace, but is drawn away as quickly as possible into the condensing chambers.

The art of making lampblack necessitates absolute control of the feed of the oil, also control of the supply of air. Unless this is done, neither the maximum quantity nor a high quality can be produced. Should the furnace become too cool, the black deposited will contain a large percentage of what it known as free oil. On the other hand, if the furnace is too hot, the black will be consumed in the furnace and the yield to that extent decreased.

The expert manufacturer of oil lampblack relies to a great extent upon the appearance of the flame in the furnace, and is just as expert in his way as those who are employed in the manufacture of steel, who are able by observing the color of the flame issuing from the convertor to determine whether the impurities in the iron have been eliminated. So the expert lampblack burner, by means of a peep-hole to each furnace, is able to determine the quantity of air which should be admitted to keep up the combustion to that point which will produce the greatest yield or the highest grade of black. The adjustment of air to the furnace needs to be regulated to the atmospheric condition, and no arbitrary rule can be set down as a guide.

The users of lampblack, however, while academically interested in knowing how it is made, will find it more profitable and interesting to know how the purity and value of lampblack may be determined, and in what way they may detect spurious substitutes, or adulteration.

The great difference between true lampblack and charcoal is in the finer division of the carbon, and it is this characteristic which gives all lampblacks greater opacity, covering, spreading, tinctorial and carrying power—attributes impossible to obtain to the same extent with charcoal or an admixture of charcoal. Some of the charcoals —for instance those of bone and ivory, as also some of the charcoal residues—may be blacker than pure lampblack, but they all lack the intrinsic value of lampblack,—viz., purity of carbon, fineness of the particles forming the same, permanency of color, and tinting or staining power. Pure lampblack will hold its color while many charcoal blacks will not.

Lampblack, by reason of the particles forming it being exceedingly minute, will cover more surface and carry and spread more uniformly. Therefore it is more economical to use as compared with any charcoal residuums. No charcoal or residuum black has the staining power of lampblack, and although they may be cheaper by the pound, they are more expensive by surface measurement.

With suitable scientific apparatus, appliances and materials, users of black pigments can readily discover the relative and comparative value of lampblacks or charcoal blacks, and will also be in a position to detect impurities or adulterations.

CHAPTER XIII

HYDRO-CARBON GAS BLACK

HYDRO-CARBON gas black is the king of all black pigments—a product unique. Of all the substances in nature, or those produced by man, this product is in a more finely divided state than any other; the particles forming it are more minute than those of any other known pigment. In the dry state it is the blackest pigment which has ever been made and nearly all other substances called black appear gray by comparison.

It was unfortunate indeed that this exceedingly valuable lampblack, which was first produced in the United States on a commercial scale about 1875, was given the lengthy name of "Hydro-Carbon Black"; later "Carbon Gas Black"; and, at the present time, has been abbreviated to "Carbon Black." Had it not been given such a long title, its name would doubtless have distinguished it clearly from many other members of the large family of hydro-carbons. As matters now stand, however, the name commonly applied to this pigment—carbon black—has resulted in confusion, not only in the minds of users of the black, but also among the minds of the public in general. The original name undoubtedly came from one of the early manufacturing concerns that was known as the "Hydro-Carbon Black Company."

Before attempting to give a technical description of this pigment, known as hydro-carbon gas black, it is necessary to know something about the family of carbons and hydro-carbons, of which their number is legion. The scientific hypothesis is that carbon, which was originally stored in the earth, found its way to the surface when our planet was in a molten mass of incandescence. In the beginning, when mother earth was without form, and void, and before water had covered the surface, the atmosphere was composed principally of carbonic dioxide and nitrogen. With the formation of water, and an atmosphere containing nitrogen and dioxide of carbon, conditions were favorable to vegetable life which then appeared upon the earth in the form of myriads of ferns of the horse-tail variety. The profusion of plant life during the carboniferous age absorbed the excess of dioxides of carbon in the atmosphere, converting this gas by the action of light and heat into chlorophyl, and by this mysterious process, which science cannot explain, dioxide of carbon was assimilated into vegetable organisms.

The vegetable growth thus brought into being, subsequently became buried deep below the surface, forming the different kinds of coal, also petroleum oil and gas.

To give hydro-carbon black the name carbon, merely designating it as a black, does not differentiate it from the thousands of other carbons and hydro-carbons, all of which vary in their purity of carbon as also in their physical properties. We have the natural carbons, some of them vegetable and others possibly of volcanic origin, those of the former being in the form of bituminous and anthracite coal; lignite; and of the latter, asphalt, pitch, graphite, ozocerite, gilsonite, etc.; and lastly, the valuable crystalline carbon, the diamond.

It will be noted that some of these carbons have a specific or definite name which distinguishes them from any other carbons. When we speak of a diamond, we know that it is a pure crystalline form of carbon containing only a minute percentage of silica. A person does not go into a jewellery store and ask specifically for "a 2⅓ carat carbon." The average person merely asks for "a diamond" and the jeweller, of course, understands what is wanted. But, if one asks for "carbon black," how is anyone to know what particular kind of carbon is desired: bituminous or anthracite coal; lignite; bitumen or graphite; oil, or gas retort carbon? All of these are carbons and all are black, but none of them are lampblack.

To add to the confusion, those who first manufactured carbons for the open arc light, called their product "carbons."

Confusion again is likely to occur when a product does not bear a specific name. This is exemplified in the case of graphite, known also as plumbago, and by many called black lead,—a misnomer, for though it is black, yet it is not lead and contains not a particle of lead in its composition. The result of the error made years ago in misnaming graphite, *black lead,* will doubtless continue as regards to lead pencils, which are really made of graphite, one of the pure forms of carbon.

The same may be said concerning carbon gas black made from natural gas. It is truly a carbon, and certainly it is black, but its name does not differentiate it from coals which are also carbon and black, or from coal, oil and gas retort cokes, all of which are black forms of carbon, but with entirely different physical properties.

Among the many other carbons are carbon electric-light points, usually termed carbons; carbon brushes for electric cars; carbon electrodes; carbon filaments for the incandescent light; and carbon dry batteries. All of these are carbons, but all differ vastly from carbon gas black.

The carbon which is used in the open arc is made from gas or oil retort coke, both being by-products, one in the manufacture of illuminating gas, the other in oil distillation. These are mixed with another carbon, usually tar pitch, which is used as a binder, and produce what are known as electric-light carbons or pencils.

The same material is used for the manufacture of carbon brushes, and these are coated over with another carbon graphite, and are termed graphitized carbon brushes.

The carbon used in the enclosed arc, which must be exceedingly pure for the purpose, is made of oil lampblack, a substance produced from tar oil, and another one of the hydro-carbons.

Carbon filament is bamboo, carbonized, used for the incandescent light. Gas retort coke is used in the carbon batteries.

All carbons, with the exception of lampblack, used in electrical work, are allotropic forms of carbon, hard and close-grained, and are entirely different from the light, flocculent black powder made from natural gas and which is now so extensively used in the manufacture of printing ink.

From the foregoing it will be seen that different kinds of carbon are produced in a variety of forms, dependent upon the substance treated and the process of manufacture. It should be clear that all carbons have different physical properties making them peculiarly suited to their varied uses.

Natural gas, or gas produced from the distillation of coal or oil, by different processes or methods of treatment, may be converted into the following kinds of carbon: gas retort carbon; graphite or hydro-carbon gas black. Natural gas is found in many parts of the United States and varies considerably. The natural gas which contains the lowest percentage of carbon dioxide and nitrogen produces the largest quantity of hydro-carbon gas black per 1,000 cubic feet of gas.

Methane, a stable colorless gas, and natural gas are erroneously used as synonymous terms, probably due to the fact that most of the natural gas contains a large percentage of methane. Methane gas contains 33.5 pounds of carbon per 1000 cubic feet, and approximately this quantity of an allotropic form of carbon has been obtained by the disruption of this gas in closed retorts or tubes, heated to high temperatures.

The Solar Carbon Company, of Pittsburgh, Pennsylvania, in about the year 1883 erected a plant to make crude carbon from natural gas, to be utilized in the manufacture of electric-light carbons. This company located its works at Dee, Pennsylvania, the plant consisting of a series of clay ovens in which the natural gas was ignited, with sufficient air to permit of combustion.

The carbon produced in these ovens was of two distinct kinds: graphite, of a steel-gray color; and a close-grained carbon resembling that made in gas and oil retorts, but considerably harder, some of the lumps cutting glass readily. Mixed with these two different carbons was a small percentage of flocculent black, similar in color and texture to hydro-carbon gas black.

Experimentation by this company proved that none of these carbons were suitable for its purpose. The graphite was in a form which could not be used by this company to advantage and the hard form of carbon was extremely difficult to mill; gave too great resistance, and was not so satisfactory for the making of the open arc carbons as that which could be obtained much more cheaply, i.e., gas retort and oil retort carbons. In consequence, the works were abandoned, and so far as we are aware, the manufacture of carbon from natural gas in closed retorts has not been again attempted on a commercial basis.

Hydro-carbon gas black, which is the pigment now used in the manufacture of all kinds of black printing ink, and is made principally in the States of West Virginia, Louisiana and Pennsylvania, is so unique a product, and used for such a great diversity of purposes, that its history and method of manufacture should prove interesting.

It has long been the dream of the chemist to obtain the maximum luminosity at the minimum expenditure of energy and least waste, as it has been to obtain all of the carbon contained in natural gas. Both of these problems have not been completely solved, and they are interrelated. Luminous gas or the light from oil or candle flame is due to the presence of solid particles heated by the flame to incandescence. Apparently in the dark zone of luminous flame, decomposition of the hydrogen occurs and liberates the carbon in minute particles, these being heated to incandescence in the upper portion of the flame and producing the light. The manner in which these solid particles are liberated is yet unknown. It is known, however, that the outer and non-luminous envelope of the flame is cooled by the outer air which is sucked in by the flame itself, and combustion in the outer air of the flame is not completed, and due to this incomplete combustion of the outer surface of the flame, carbon monoxide is liberated into the air.

It is generally understood that lumination is augmented by the increased temperature of the carbon in state of incandescence. It has been demonstrated that an incandescent lamp in which the filament is heated nearly to a point of destruction by vaporization shows increased light efficiency. This is borne out as regards the arc lamp, which is more efficient in lumination than the incandescent filament, due to the higher temperature produced in the arc. What is true of light produced by electricity is true of the more humble lighting devices. The light of the candle is less than that of the oil lamp. The light of coal gas is greater than that of the oil lamp, but less than that of acetylene gas, and by means of the carbon arc the greatest light, also the greatest heat, are obtained.

Chemists in their attempt to force a product to give up the maximum quantity of that which they wish to obtain, are often led astray; especially is this so if they are not fully acquainted with the attributes, characteristics and qualities of that product which they wish to make.

The content of carbon in natural gas of necessity varies in proportion to the percentage of ethane, methane, nitrogen and dioxide of carbon, and yet it has been generally demonstrated by chemists that natural gas contains 33 or more percentage of carbon per thousand feet of gas, but none of them have been able to prove that anything like this percentage of hydro-carbon gas black is obtainable from 1,000 feet of gas. It is true that in experiments carried on by the Mellen Institute of Pittsburgh and also in the Bureau of Mines that 30 per cent of a graphitic form of carbon has been obtained from 1,000 feet of gas. This is nothing new. It was done years ago, but by the "cracking" processes employed, only a hard, allotropic form of carbon resulted, which is not suitable and cannot be used in the manufacture of printing ink, or for any of the purposes for which hydro-carbon gas black is now employed in the arts and industries.

To understand the difference in the carbons produced by different methods or processes it is necessary to know something about the different forms of carbon. Carbon in the solid takes many forms which have distinct physical properties. It would appear that the principal two causes for these differences are heat and motion. The action of heat on carbon is well understood. The difference between coals, especially that between bituminous and anthracite, is in all probability due to the different temperatures to which the wood which was carbonized into coal was subjected, the heat which produced anthracite being greater than that which produced bituminous. This heat, no doubt, is far less than that which produces the graphitic forms of carbon, as also the crystalline carbon in the form of a diamond. It has been clearly demonstrated that when a substance rich in hydro-carbon is subjected continuously to a high temperature the carbon is hard, close-grained and adamantine, and that in contradistinction the amorphous and flocculent forms of carbon similar to lampblack are obtained by the rapid dissociation of any product rich in carbon, such as the heat generated in an arc, or in the electric furnace.

The adamantine forms of carbon have all been produced under a continued high temperature, not only those found in nature, but also those produced by man. Of the former, we have the many kinds of coal, and lignite and graphite. Of the latter there are the oil retort and gas retort carbons; the one formed on the inner surface of the retorts in the manufacture of gas—the other forming in a similar manner in the retorts in the distillation of oils. There are also the coal coke and graphite, the latter now produced in electric furnaces. The graphitic form of carbon is produced in the heat of the convertor in the manufacture of steel.

Adamantine carbons can be produced direct from any hydro-carbon vapor, if the temperature is high and continuous, and a similar carbon be obtained by the continued application of heat, from the amorphous forms of carbon.

The manufacturers of carbon points, etc., who use lampblack on account of its purity of carbon, take the lampblack, which is an amorphous form of carbon, bake it and convert it into a hard carbon of great electrical resistance.

It will be seen that an amorphous or flocculent form of carbon can be converted into a hard carbon by heat, but the process has not yet been reversed. The flocculent or amorphous forms of carbon are in an exceedingly finely divided state, and it is this physical character which makes them so exceedingly valuable for the manufacture of black printing inks.

It is not known why the carbon is liberated in minute particles in a gas flame. It is known that in some manner the burning of the hydrogen liberates the carbon, which in the minute particles is brought in contact with oxygen in the atmospheric air, and by the heat of the flame is put in a state of incandescence. When this flocculent form of carbon is deposited it holds fixed a considerable percentage of air, as also a percentage of occluded gases. When to this carbon in a finely divided state heat is applied, the occluded gases, as also the air between the particles, are driven off, and electronic or molecular activity takes place, which brings the minutest particles, forming the carbon, into closer proximity, and converts the carbon into a homogeneous adamantine mass. All solid forms of carbon are made harder by heat and pressure.

It is only within recent years that uses are being found for many of these adamantine forms of carbon which were mostly produced as by-products. The oil refining companies for many years threw away the hard form of carbon which adhered to the inner surface of their retorts in the distillation of petroleum oils, and it was only about 30 years ago that an enormous hill of this carbon, which had been thrown out from the retorts, could be seen between Cleveland and Newburg. At that time the largest quantity of electric-light carbons were made in the city of Cleveland. The hill of carbon referred to lay exposed for anyone to take, and some of the poor people in and around Newburg used to collect the carbon which they put on their fires, having discovered the fact that it gave out considerable heat.

A new method called "The Production of Carbon Black by the Electric Arc," for use in printing ink, is announced, but the writer believes it has not as yet advanced beyond the experimental stage.

CHAPTER XIV

THE BIRTH OF AN INDUSTRY

SINCE the close of that fateful year, 1914, beginning the Great War, no scientific discovery has gained more respectful attention than William Henry Perkin's happy stumble upon mauve, or aniline-purple as it came to be called. Although well known to chemists, and consistently used by them in their efforts to arouse in the public some recognition of chemistry as a factor of well-being in the State, the narrative had uniformly failed in its purpose. The bludgeon of war was required to coax the Allies into an appreciation of their debt to chemistry.

It may be assumed with confidence that the chain of events leading from aniline-purple to alizarin continues to elude the mental grasp of the majority; but it is happily unquestionable that an active popular interest in coal-tar and its constituents is gradually becoming more widespread, and may be welcomed as the germ of an intelligent public opinion on matters connected therewith. Perhaps by the time there is no more coal tar, aniline colors will have become the subject of dinner-table persiflage.

Speculation as to what would have happened, if something which did happen had not happened, may sometimes lead to strange conclusions. Although the experiment which caused Perkin to discover the first aniline color was in strict obedience to the scientific principles of chemistry prevailing in 1856, the result was purely accidental, because the purpose in the discoverer's mind was to produce quinine. Supposing Perkin had produced quinine, it is conceivable that his name would never have been associated with coal-tar colors, because the rewards which ultimately released him from chemical manufacture to pursue the purely scientific lines he desired to follow would have ensued very rapidly on the particular result he had hoped to achieve. The path to a competence which he so tenaciously followed was richly strewn by him with benefits to the organic chemical industry, but it was a thorny path, whereas the direct conversion of allyltoluidine into quinine would have opened a golden road.

On the other hand it may be affirmed that, even if Perkin's experiment had led him to the result for which he hoped, the recognition of benzene, naphthalene and anthracene as fruitful sources of artificial coloring matters could not have been long delayed. The chemical atmosphere of the eighteen-fifties was overcharged with information which accident might at any moment precipitate in the form of such a discovery. In 1858, an obscure German student made experiments destined to lead him independently of Perkin—because their ultimate application to coal-tar chemistry could not, by any possibility, have been foreseen—to the development of a field which has brought to the dye house and the printing machine a greater number of dyeing agents than lie to the credit of any other branch of color chemistry, incidentally promoting the name of Peter Griess to the front rank of chemists. Whilst it is highly probable that Perkin's discovery hastened the manufacture of magenta—the first great contribution to the subject by a countryman of Lavoisier, the great French chemist—it is equally probable that many years could not have passed before the coloring matter emerged from the laboratory of Perkin's immortal teacher Hofmann, because it actually arose as an unrecognized by-product of an experiment by Natanson in 1856, and again in the hands of Hofmann himself two years later.

In this connection it is arresting to reflect that until the demands of the infant industry had compelled Perkin to develop Béchamp's method of preparing aniline from nitrobenzene, Hofmann laboriously assembled the aniline required for his experiments by heating indigo with caustic potash. This process, due to Fritsche, was a variant on that by which Unverdorben first obtained aniline in 1826, namely, destructive distillation of indigo, a transformation by which the oldest and most respectable of natural coloring matters may be said to have accelerated its own ruin.

From one standpoint, Hofmann may be regarded as having made contributions to the foundations of color chemistry even greater than those of Perkin, although his quota was not so spectacular: for whilst Perkin developed the technical skill and commanded the qualities of patience and perseverance necessary to translating laboratory experiments into factory operations, thus laying the foundation of the modern organic chemical industry, Hofmann provided the theoretical groundwork and equipped the human agents, including Perkin himself, whose Memorial Lecture delivered to the Chemical Society in 1896 paid a generous tribute to his illustrious predecessor.

In persons of sensibility and imagination, a peculiar thrill is engendered by dissecting the humble beginnings of great events, and those who take interest in tracing the early history of aniline color chemistry in its human aspects must fall under the spell of Perkin's autobiographical

Hofmann eulogium. The play of influences there portrayed began when the lad, at less than thirteen, came under the ægis of Thomas Hall, whose own chemical enthusiasm had been cherished and stimulated by Hofmann at the Royal College of Chemistry: it was a natural process, therefore, to transfer the favorite pupil, by this time in his fifteenth year and lecture-assistant at the City of London School, to direct association with the master-mind. Perkin has recorded the probability that words of Hofmann written in 1849 led him to make in 1856 the experiment which carried him to fame and fortune, whilst his last great achievement in this field, the synthesis of alizarin in 1869, was made possible and was facilitated by the circumstance that the first subject of research suggested to him by Hofmann had been an inquiry into the chemistry of anthracene.

Furthermore, it was Hofmann who induced his pupil Charles Mansfield to investigate the feasibility of separating the coal-tar hydrocarbons by physical means, and thus to render pure benzene a primary raw material for dye manufacture: it was Hofmann who trained E. C. Nicholson and H. Medlock, both of whom in 1860 independently filed a patent for the arsenic acid magenta process; finally, it was Hofmann who, in 1858, discovered Peter Griess in Marburg, supplemented his training at the Royal College of Chemistry and established him in Allsopp's brewery, where he modestly pursued his illustrious career as the founder and developer of diazonium chemistry.

The abundance of material which Griess's discovery has added to the storehouse of chemical knowledge may be appreciated by realizing that the number of theoretically possible azo dyes has been estimated at three millions of individuals. Technically, the most important outcome was the discovery of direct-cotton colors in 1885, thus enabling the dyer to use a vast range of substances independently of mordants. An entirely different class of coloring matter was introduced in 1893 by Vidal's discovery of sulphur-black, whilst the same decade witnessed the culminating triumph of the indigo campaign, the synthetic product being marketed in quantity during 1897. Four years later, Bohn's discovery of the indanthrene group supplied the textile trade with dyes of such exemplary fastness towards light and washing that they are able to outlive the fabrics they adorn.

Thus, within the period of half a century, there sprang from the seed of accident a tree of knowledge under whose branches shelter and refreshment are provided for a multitude of workers. The development of the coal-tar color industry and the manufacture of artificial drugs and perfumes ancillary thereto have reacted with stimulating effect upon the heavy chemical industry, and indeed have been rendered possible only by the response which that industry has made to the stimulus; together they constitute one of the most amazing achievements of civilization. To the chemist they are the source of joy and pride, inasmuch as they represent an economic justification for the pursuit of his beloved science and hasten the day when that science will cease to be the Cinderella of the arts. On the general public they have bestowed countless æsthetic benefits, accepted for the most part without inquiry whence they come.

These benefits are not limited to the products of textile manufacture, but accrue also to the printer's art. The wealth of design, beauty of shade and general technical excellence of modern illustrated books and papers could not have been brought as commonplaces into every home if the artistry and craftsmanship for which they stand a monument had not been made articulate by products of the research laboratory and color factory. The educative effect of these co-operative results is incalculable. All those of middle age who recall the simple periodicals and crude advertisement posters of boyhood will agree that a new world of literary gratification and street-side entertainment has revealed itself to the new generation by imperceptible stages, providing trustworthy impressions which may be assimilated without effort, and with the advantageous accompaniment of improvement in taste. The sum of these contacts has enhanced the general welfare of communities brought under its influence by extending the field of their interest in life, broadening their sympathies with neighboring peoples and facilitating their apprehension of alien concepts.

CHAPTER XV

COLORED PIGMENTS FOR PRINTING INK—NATURAL AND ARTIFICIAL

THE division of all matter into the two classes, organic and inorganic, is accompanied, as are many chemical classifications, by an element of indefiniteness, which becomes apparent as we approach the dividing line. There are certain substances possessing the properties of each class which could be assigned to either, according to the perspective of the individual investigator.

Of the eighty-odd elements, of which all substance is composed, carbon alone has stood as the representative of the organic kingdom. But in spite of this apparently unfair distribution, the number of organic compounds far exceeds the number of inorganic. All animal and vegetable life depends upon the carbon atom for the nucleus of its molecular structure, but many of the other elements also enter in its composition of which the most important is hydrogen. If, therefore, we consider the hydrocarbons as the basis of organic compounds, there is less confusion in the classification of substances. Carbon, by itself, is inorganic, as are all the other elements, but when combined with hydrogen, it becomes the starting point of organic chemistry.

There need be no uncertainty in the minds of the color chemists regarding the classification of dyestuffs and pigments. Although the carbon atom is present in Iron Blue

(Ferri-Ferrocyanide) and in Magnesia (Magnesium Carbonate), they could not be listed among the organic colors because they are not derivatives of the hydrocarbons.

It was W. H. Perkin, an English chemist, who, in 1856, by accident produced synthetically the first artificial dyestuff, which is known as Perkin's Purple, or more often, as Mauveine. The history of the artificial dye industry is one which makes very interesting reading, but it is beyond the scope of this chapter to refer to it in detail. The chapter "Birth of an Industry" gives a short history of the origin of coal-tar dyes. Suffice it to say, however, that contrary to popular belief, the coal-tar industry did not have its inception in Germany, but it was Germany that developed it to its present-day proportions.

Coal, preferably soft coal, is the starting point in the manufacture of artificial organic pigments. If coal is thoroughly ignited in stoves, with an abundance of air, the three principal products formed are: water vapor, carbon dioxide, and ash. If coal be heated equally hot inside a long cast-iron retort or earthen retort, with the exclusion of air, then a large number of products are formed, the four chief ones being coal gas, ammoniacal liquors, coal tar, and coke. Coal tar, once a great nuisance, is the only substance obtained which is of importance to the dye industry. It contains more compounds than the other three products combined. One ton of coal yields about one hundred pounds of coal tar, which has a specific gravity of 1.10 to 1.26.

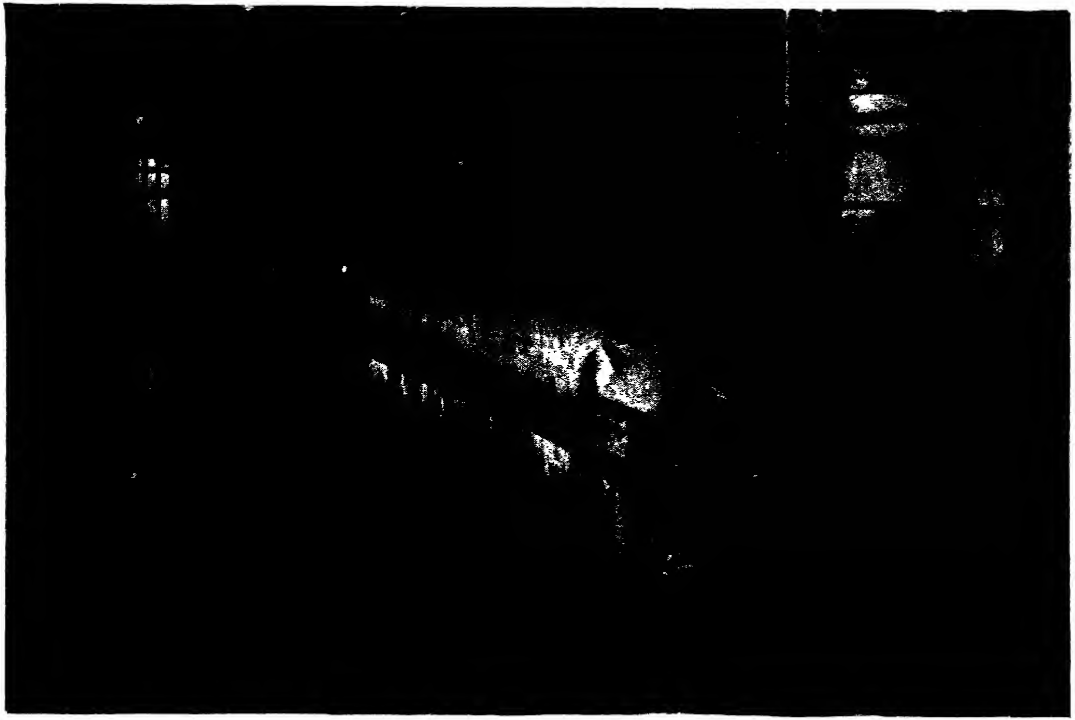
In order to split this tar into its component parts, it is subjected to fractional distillation and the fractions run into separate receivers. The process of distillation is carried on until a temperature of 400° C. is obtained, when about 55 per cent of the original tar remains as a thick black pitch which is solid at room temperatures.

The names and distillation temperatures of the fractions caught in the receivers are as folows:

First light oil	to 105° C.
Light oil	to 170° C. — 210° C.
Carbolic or medium oil	to 230° C.
Creosote or heavy oil	to 270° C.
Anthracene or "green" oil	to 270° C. — 400° C.

The distillation end points of the several fractions may vary somewhat on account of the nature of the coal tar, or on account of the substance desired. Sometimes too, the number of fractions may be only three or four, depending upon plant conditions. By further treatment of the several fractions, such as fractional distillation, and washing with sulphuric acid and caustic soda, there are obtained the valuable materials in their pure state for the manufacture of dyes. These fundamental materials are: benzene, toluene, xylene, phenols, naphthalene, anthracene, etc. In this country the manufacture of the above compounds is in the hands of a few large companies, who as a rule do not attempt to fabricate these compounds into more complex compounds, but rather prefer to sell them to others whose prime business it is to make intermediates and dyes. Thus far we have traced the steps taken in obtaining the list of compounds from benzene to anthracene, all obtained from coal, and now we shall endeavor to picture in a non-technical way the conversion of the above substances into intermediates, and these in turn into dyestuffs.

Benzene and its homologues belong to a series of compounds known as the aromatic series, and these com-



PRECIPITATING VATS AND FILTER PRESSES USED IN THE MANUFACTURE OF PIGMENTS

pounds taken as a class are relatively speaking chemically reactive. Benzene, for example, reacts with nitric acid to form nitro-benzene, and this in turn with fuming nitric acid to form dinitro-benzene. Other reagents, such as sulphuric acid, nitrous acid, ammonia, nascent hydrogen, chlorine, bromine, and caustic soda, have the power of uniting with or changing the structure of members of the aromatic series of compounds, and the resulting products of these unions are the so-called "intermediates." Not all, however, are valuable as sources of dyestuffs, for intermediates as a class not only produce dyestuffs, but medicines, perfumes, photographic chemicals and explosives as well.

The manufacturer of intermediates must thoroughly understand the chemistry of his business. He must know the importance of time, temperature, concentration and sometimes pressure in bringing about the desired reaction. The main difficulty he encounters is due to the existence in large numbers of isomeric substances. Isomers are two or more compounds having exactly the same chemical composition, but differing from each other only in the arrangement of the atoms within the molecule.

In the process of making a certain substance, the manufacturer must follow carefully the requirements of time, temperature and concentration, or the resulting product will contain too large a proportion of the isomers of that substance and cannot be relied upon to give the desired color.

For example, when we speak of dinitro-benzene, we must realize that there are three possible compounds possessing this same formula. The benzene nucleus is in the form of a hexagon with a carbon atom at each of the six angles. To each of the carbon atoms is attached a hydrogen atom. When benzene is acted upon by nitric acid under the proper condition, the hydrogen atoms are replaced in the molecule by the nitro group NO_2. If the reaction is stopped when only two nitro groups have been substituted, we have dinitro-benzene, but there are three possible dinitro-benzenes. If the nitro groups happen to attach to two carbon atoms adjacent to each other, we have the ortho-dinitro-benzene. If one CH group lies between the two nitro groups, we have the meta-dinitro-benzene, and if two CH groups lie between, we have the para compound of that name.

The one of these three that is produced in the largest proportion depends upon the manufacturer's control over the conditions mentioned above, and his knowledge of the chemical requirements

It was stated above that not all intermediates produce dyestuffs. Every dye or intermediate capable of producing a dye, must contain one or more chromophoric groups, such as —N=N— (Monoazo); =CO—; =N—N= (diazo); =C=O; =C=S; =C=N—. These groups are not self-existent, but when attached to an aromatic group, there exists the so-called "chromogen." The "chromogen" is not a dye, but it becomes a dye upon the entrance into the molecule of such groups as will give it the power of forming salts. These groups are called "Auxochromes," or color assistants, e. g., OH or NH_2. The auxochrome is a powerful factor in determining the strength and shade of the color. An acid auxochrome such as (OH) will increase greatly the color strength when attached to an acid chromogen. A basic auxochrome such as (NH_2) is more advantageous in a basic chromogen. Such intermediates, having the above characteristics, are capable of forming dyes. The intermediates by interaction brought about by binding agents, such as sulphur, nitrous or oxalic acids, or by processes known as oxidation, dehydration, reduction, condensation, substitution, hydroxylation, etc., yield true dyes. True dyes in short are compounds having the property of coloring vegetable or animal fibres or inorganic matter with or without the aid of a mordant (grounding agent). The manufacture of dyes and of pigments made from dyes is usually carried out by the same company as the pigment is, but one step beyond the dye. This, however, is not always true, as there are several companies who busy themselves only with the manufacture of pigments from dyes.

A pigment is generally understood to be any substance very finely subdivided, which is insoluble in either water or oils commonly used to produce inks, paints, etc. Organic pigments, therefore, are pigments which consist wholly or in part of dyes rendered insoluble in water and oil. Organic pigments, which are made without precipitation upon a base, such as gloss white, barium sulphate or aluminum hydrate, are known as C. P. colors or toners; those having a base are known as reduced colors or lakes.

The following classification will serve to indicate both the chemical constitution and pigmental adaptability of the more common dyes:

1. To the azo group belong the most numerous of the dyestuffs. It contains the chromophor —N=N—. There are three divisions, as follows:

Amido-azo-dyes
Oxyazo dyes
Tetrazo dyes

All are important to the pigment maker because of their permanency and tinctorial strength; the latter quality allows the use of a high percentage of base.

The amido azo colors are of basic nature and are soluble in water. To this class belong chrysoidine, metanil yellow and Bismarck brown.

The oxyazo compounds are of acid nature and require the presence of a sulphonic acid group to render soluble in water. Ponceau 2 R, Crocein Scarlet and Orange 2 belong to this class.

The tetrazo dyes contain more than one chromophor —N=N— and includes Biebrich Scarlet, Bordeaux G, Acid Brown, Naphthol Black, etc.

The adjective azo pigments are made directly by precipitating a dyestuff with an organic group of opposite character.

2. The oxyketones or oxyquinones form another very important class, which, because of their permanency to light and chemicals, rank among the foremost of dyestuffs used by the pigment maker.

They contain the powerful chromophore =C=O which requires the union with certain metallic oxides for the full development of the color.

Alizarine is the most important member and is represented among the pigments by the well-known artificial Madder Lake.

3. The triphenyl methane colors include some of the most brilliant pigments known. They are not, however, as a rule permanent to light. There are three divisions.

The rosanline group with the chromophore =C—NH— includes Malachite Green, Magenta, Methyl Violet and Aniline Blue. The Rosolic Acid group with the chromophore =C—O—, is not so important and is represented by Aurine.

The phthalein group with the chromophore=C—O—CO includes the important Eosines, Erythrosine, Rhodamine, Rose Bengal and Cœruleine.

4. Nitro Derivatives.

The dyes of this class are not important color producers, as most of them are either poisonous or explosive. One, however, Naphthol Yellows, finds application and produces a very fast yellow shade pigment.

5. Hydrazone and Pyrazolone coloring matter.

These dyes are similar to the azo dyes. The important one is Tartrazine.

6. The azomethane and Stillbene dyes.

These are of theoretical interest only.

7. The Azines, Oxazines and Thioazines.

In this class the more important ones are Methylene Blue, Methylene Green, Safranine, Mauvein, Induline and Thioflavine.

8. Quinoline and Acridine.

Quinoline Yellow is the dye in this class best known to the Lake manufacturers.

9. Xanthones, Flavones, Cumarines and Indones are represented by certain dyes of vegetable origin, such as Quercitron, Morin, Maclurin, Fisetin, etc.

10. Aniline Black.

By oxidizing Aniline Oil in the presence of Copper or Vanadium salts with the aid of sodium chlorate, there is produced a water insoluble compound known as Aniline Black. This finds little application as a pigment on account of its relative coarseness and its non-drying characteristics.

11. Indigo.

While it is possible to produce a pigment from Indigo, the same is utterly unadaptable for printing purposes.

We shall now examine the methods used in converting the dyes into usable pigments. Before doing so, it might be well to mention that the dyes of low molecular weight in each class are of the lighter colors,—yellow, orange, brown or bright red. As the shade deepens into crimson, bordeaux, maroon or violet, the molecular weight increases and is highest in dark shaded dyes, such as blues, greens and blacks. Almost all dyes can be precipitated or rendered water insoluble by one of the six following methods:

(1) Colors precipitated by barium chloride.

These dyes are the so-called "sulphonic acid dyes." A typical formula is the folowing:

100 parts barium sulphate	
1 to 5 parts Quinoline Yellow	1:100 water
2 to 10 parts barium chloride	10:100 water

The above formula requires three tanks for manipulation. In one the barium sulphate is dispersed in water; in the second tank the dye is dissolved in water, in the ratio of 1 part of dye to 100 parts of water; while in the third tank, barium chloride is dissolved in water, in the ratio of 1 part of barium chloride to 10 parts of water. The contents of tanks 2 and 3 are allowed to run in precipitation ratio into tank 1. The rate of addition, the temperature of solutions, the violence of agitation, all have an effect on the quality of the pigment produced, and it is beyond the purpose of this chapter to discuss these variable factors in detail. Each manufacturer believes his method the best and cautiously guards his process. Some of the dyes rendered insoluble by barium chloride are Naphthol Yellow, Orange R, Lithol Red, Red for

Lake P and C. Acid Violet, Patent Blue, Acid Green, Naphthol Green, etc. As hereinbefore stated, the dyes may or may not be precipitated upon a base. This applies to all dyes.

(2) Coloring matter precipitated by lead salts.

Lead acetate is usually used and the dyes rendered insoluble by it are Eosine, Erythrosine, Phloxine and Rose Bengal.

(3) Dyes precipitated with tannic or other weak organic and inorganic acid.

Tannic acid is usually used in conjunction with tartar emetic in making lake colors of the so-called "basic dyes," such as Methyl Violet, Malachite Green, Victoria Blue, Victoria Green, etc. Other mordants in this class are the vegetable and animal soaps, Turkey red oil, casein, albumen, sodium silicate, arsenious acid and sodium phosphate.

(4) Dyes precipitated with Aluminum Hydrate or similar materials.

Pigments made by this method are not, strictly speaking, precipitated colors. The dyestuff is really absorbed by the gelatinous freshly precipitated Aluminum Hydrate. This material has the peculiar property of absorbing both acid and basic dyes. When other bases, such as Barium Sulphate, are used with Aluminum Hydrate, better working pigments are obtained.

(5) Lakes from adjective colors.

It is possible to precipitate a basic dye by means of an acid dye, but this method is unsuccessful in making practical pigments for the printer.

(6) Insoluble azo and diazo colors.

This class of dyes does not require any mordanting or fixing agents as they are water insoluble by themselves.

The color manufacturer, instead of starting with the dyes, uses the intermediates from which they are made. Paranitraniline red is at once the most typical and most important dye in this class and its manufacture will be explained.

SOLUTION A

24 parts paranitraniline
12⅕ parts sodium nitrite
60 parts hydrochloric acid
250 parts water

SOLUTION B

7 parts caustic soda
25 parts Beta naphthol
250 parts water

Paranitraniline is diazotised by means of sodium nitrite and hydrochloric acid at a temperature below 40° F. Beta naphthol is made soluble by means of caustic soda. Solutions A and B are added together in a separate tank with constant stirring and boiled. The resultant product is the "para" red so well known to the printing-ink manufacturer.

After the dye has been made into a pigment by one of the above processes, the next operation is to wash it free from any by-products. This can be done by allowing the pigment to settle in the precipitation tank, decanting off the mother liquor and then adding more water. This operation is usually performed two or three times until the wash water shows little or no traces of soluble matter. Or, the entire batch of pigment and mother liquor may be pumped directly into a filter press and washed there, which brings us one step closer to a finished product.

It is necessary to express as much water from the pigment as possible, and this is done in one of several types of filter presses. The pulp (pigment and water) is now ready for the drier. The pulp is usually placed on racks, which in turn fit into specially made trucks. The drier may hold from six to thirty trucks, and is operated at a temperature which will not injure the shade or softness of the dry color. After being thoroughly dried, the resulting lumps of dry color are ground into a fine powder and it is in this condition that the printing-ink grinder receives it and incorporates it with the proper varnish to make inks. Not always is the pulp dried out before it reaches the hands of the grinder. It is possible with most colors to add varnish directly to the pulp in a mixer, and after sufficient mixing to separate the water from the pigment-varnish mixture. Not only is this short-cut a time and money saver, but the resulting ink usually will print with a higher finish. In fact some colors are so delicate that they will not stand any drying whatever and must be put through this short-cut process.

Prior to the discovery of the manufacture of dyes, most of the pigments used by both printers and painters were of the inorganic variety, with the exception of a few made from animal and vegetable juices. The brilliant shades of today were unknown seventy to eighty years ago, and while the present generation can truly feel proud of what it has produced thus far, yet these colors of our age are not by any means the "finis" of the dry color industry. As the chemist learns, the printer will be supplied with even a larger variety of colors; colors that are more permanent and faster to light, acid, alkali, and alcohol; colors that will bake better; colors, in short, that will meet the printing-ink manufacturer's requirements more perfectly.

CHAPTER XVI

THE HISTORY OF PLATE PRINTING AND INTAGLIO INKS

PLATE printing or intaglio inks have been aptly referred to as "the aristocrats of the printing-ink family," as for centuries they have been used in making prints from the finest etched steel and copper plates. The history of these inks is interesting as a romance, being entwined with the ambitions for immortality of many of the world's most famous artists. It includes in succession the names of Dürer, Rembrandt, Van Dyck, Claude Lorrain, and many others down to our own Whistler. These geniuses realized that their art in painting, if owned by private individuals, would be seen by few, and further that paintings might lose their brilliancy, be damaged, or destroyed entirely, while if duplicated in permanent inks, their fame would endure through all posterity.

And so it has proven. Leonardo da Vinci's "Last Supper," one of the world's greatest masterpieces, painted on a wall of the convent Sante Maria della Grazie at Milan in 1498, is a notable example. The original painting has crumbled away, but its engraving by Raphael Morghen in 1800 and printing in plate ink has made it accessible to art galleries throughout the world, and the picture will be known for all time. This is but one instance where the painting has been lost, but prints of it in ink are preserved.

Intaglio engraving and printing from steel or copper plates are said to have originated in the shop of a Florentine goldsmith named Maso Finiguerra, much of whose work was done in niello. This was the cutting into metal—either gold, silver, copper or brass—of designs, an art which later developed to great popularity in Russia. It was the practice of niello engravers to rub their engravings full of black paste similar to modern shoeblacking. Damp paper would then be pressed in contact with the engraved plate, and the paper on being stripped off would bear a print of the design to judge the appearance when filled in with enamel. From this proof imperfections could easily be discerned and corrections made where required, and some of these niello proofs are treasured at high prices by collectors today.

Maso Finiguerra, or possibly an interested patron of his, recognized the possibility of duplicating pictures in this manner and thus began both in Germany and Italy the art of intaglio engraving and plate printing. It is supposed that Finiguerra made his first intaglio engraving and print in 1452, though it is claimed that prints were had from intaglio engraved plates in Germany as early as 1446. It was just the time that movable types were invented, when the first book—the Bible of 42 lines—was printed from type. It is a remarkable coincidence that the printing of books and the finest method of engraving and printing of illustrations were all invented about the same time.

This was a century of discovery, the one that produced printing from movable types, as well as printing from intaglio plates, but another discovery, the importance of which has been neglected, was the use of flax-seed oil in mixing artists' paints and printers' inks. Up to that time artists had used water colors, as in fresco, mixed with gums, as did the early printers. The name of the person who first applied linseed oil to printing ink is not known, but had not the printers at that time taken advantage of the drying properties of boiled linseed oil, printing would not have been the immediate success it was.

Early intaglio printers did use gum as the medium to give their inks body and keep them pasty while being used. This was the sad discovery made by many owners of precious early prints; when the paper became discolored and an attempt was made to bleach it, the ink would sometimes float away in the water bath. The use of oil in making intaglio printing inks undoubtedly began in Germany, for the prints of their earliest engraved plates withstand the methods of the bleacher. Another interesting fact regarding early intaglio prints is that the secret methods of ink-making may never be revealed, and the names of some of the first artists who took up the art of engraving will probably never be known.

The first great engraver is known as the "Master of 1466," and a contemporary is known only by the initials "E.S." with which he signed his plates. Then came another master, Martin Schongaüer, who may be considered the father of the German school, which produced some of the most famous engravers. Near the end of the fifteenth century there arose in Nuremberg the son of a goldsmith, who surpassed all previous engravers in skill, and whose fame will never die, as prints in permanent printing ink are left from his plates. This great painter and etcher was Albrecht Dürer. His paintings today would be worth many times their weight in gold, but practically all have been lost or destroyed, while the prints from his engravings and their reproduction will go on indefinitely,—another instance of the value of engraving in perpetuating the artist's fame.

The Low Countries produced a number of master engravers, though, as in Germany, their names will never be known. One is called "The Engraver of 1480," another "Master of the Shuttle," still another "Master of the Crab." Lucas von Leyden produced his first engraving in 1508 when only fifteen years of age. He not only mastered the use of engraving tools, but also the making of inks and the printing of plates. He was followed by a large number of engravers. They were soon to be outclassed by Rembrandt Van Rhyn, born in Holland in 1607, who became master of etching and printing. Though some of the prints from his plates are the most priceless of any pictures done in plate ink down to this time, he himself died in poverty.

None of these early artist engravers left, so far as is known, any record of how their plate inks were made. It was evidently a secret, like the wax acid resist used when etching their plates. Rembrandt, the master of etching, would not entrust the printing of his plates to others. He reserved that work for himself, with the result that proofs taken from the same plates seldom resemble each other. Some he would print with a mass of ink, and on others he would wipe away much of the ink, making the print lighter. So many artistic effects can be had in the inking and wiping of the plate, as well as in the toning of the ink, that many of the greatest etchers have done their own printing in order to obtain the most beautiful prints.

Among the early Italian painter engravers who had trouble with the ink used was Andrea Mantegna. The priceless prints from his plates show that the black he used was weak and that the oil with which it was mixed was not of the proper kind. Marcantonio Raimondi, born at Bologna about 1470, evidently mastered the making of ink and its use on the press. He engraved at least 650 copper plates, sixty-eight of them being copies of Albrecht Dürer prints, and they will live as masterpieces because the ink used on them was properly made.

Other great masters of painting to recognize that the only way to distribute their art was through the medium of plate ink were Rubens and Van Dyck. Rubens could find no engraver to satisfactorily interpret his paintings, so he himself founded a school of engravers. Here he trained a group of men who developed to a remarkable extent the art of engraving. They must also have mastered ink-making and printing, for their work is almost perfect.

Line engraving was not taken up in France until the reign of Louis XIV, who gave it his patronage, and thereafter it made rapid strides. A school of brilliant engravers was founded whose work for delicacy of touch and command of the burin has never been surpassed. The fineness of the plate ink used during that period added greatly to the brilliancy and permanency of these prints. In any comprehensive exhibition of works of famous engravers, the French prints of that period always stand out conspicuously for the brilliancy of the printing ink used in their production.

The history of English engraving may be said to begin with William Faithorne, who was born in 1626 or 1627. Embracing the cause of Charles I, he was imprisoned, and while in prison engraved the portrait of the Duke of Buckingham. His talent eventually secured his release, but refusing to swear allegiance to Cromwell, he was banished from his country, following which he did some of his best work in France. Faithorne had many followers, but none equalled their master. Those of his plates printed in France exhibit a better quality ink than those printed in England. Two illustrious English engravers of the early period were Robert Strange and William Sharp, the latter being called by Charles Sumner the greatest of all copper plate engravers.

Mezzotint engraving is said to have been discovered by Colonel von Siegen, who engraved a portrait of Princess Amelia of Hesse in that manner about 1662. This art was improved by Prince Rupert in 1643. It was taken up in England, where the finest mezzotint engravings were made. This process necessitated much care in the inks used in printing from the plates, owing to their delicate character. A little later, about 1662, the French artist, St. Non, invented still another method of engraving, called "Aquatint," which required the very finest of plate inks, many of them in colors.

A third method of engraving, called "Stipple," was brought from France to England by W. W. Ryland, who later tried to make a fortune by forging bank notes and who ended his days in Tyburn Prison. Stipple engraving was taken up in England by Francesco Bartolozzi, an Italian engraver. He established a school, and so popular did stipple engraving become that there are more than two thousand plates extant bearing the name of Bartolozzi as the engraver. Many of these were printed in color, so that plate ink makers and plate printers were in great demand.

Engraving for plate printing up to the beginning of the last century was usually done on copper. There was, unfortunately, no way of hardening copper, consequently plates would not stand long editions. Jacob Perkin, of Massachusetts, is said to have originated the process of engraving in soft steel and hardening the steel before printing from it. But Perkin did not stop there. After engraving in soft steel and hardening it, he devised a press for making a relief duplicate in soft steel from the hardened plate,—hardening this duplicate and then impressing it into a soft steel plate, which likewise was then hardened. This method of duplicating steel engraved plates revolutionized the bank-note and postage-stamp industry. The fineness of the lines could be maintained through long editions, and this brought further demands on the ink manufacturer. Today bank notes and postage stamps are printed on power presses at high speed, and this has added still more requirements to the working qualities, drying, brilliancy of color and permanency of plate printing or intaglio inks.

Bringing the camera to aid in the production of intaglio plates, which was perfected by Karl Klietsch and others, as told in the chapter on Rotary Intaglio Printing Inks, was the greatest step forward in popularizing plate printing and the use of intaglio inks. It brings the history up to date, and would not have been complete without mentioning the great intaglio engravers and the many methods of plate printing that have succeeded each other during the past five hundred years. And, it is interesting to note that the first engravers were obliged to master the making of *plate inks,* otherwise they would have been unable to obtain the desired effects. The case was different with typographic printers. They soon recognized that ink-making was unpleasant work and gave it over to regular ink manufacturers as a special business.

In the making of plate inks certain principles are basic, and generation after generation, if these principles were not passed on from the older to the younger, they had to be rediscovered by trial and error.

Plate printing inks are composed of an oil or binder to hold the pigment to the paper, and sometimes a drier to hasten the oxidation or drying of the ink, so it will not offset on the back of the next sheet of paper laid upon it. The most satisfactory oil for use in ink-making is linseed oil, because it oxidizes rapidly. Linseed oil in its raw state cannot be used. It must first be boiled for a long period to give it the necessary viscosity and drying properties. It is then burned, which is generally accomplished by putting the oil in small open kettles, heated over the fire, and as soon as the volatile oils begin to evaporate, they are set on fire and allowed to burn until the linseed oil has reached a certain consistency or tack. Once linseed oil and its property of oxidation were known, that by boiling and burning linseed oil it could be left stringy, or "long" as it is called, or made to break off "short"; that it could also be made thick or thin—then the greatest problem was solved in the making of plate inks.

One of the best black pigments for mixing with oil in the manufacture of ink is the soot collected from the smoke of burning oil. This was originally called lampblack and is still so termed. In printing ink lampblack has been largely superseded by hydro-carbon gas black, the soot secured by the burning of natural gas. (See chapter on "Black Pigments for Printing Ink.") Some of the more important blacks for use in plate inks were known as German black, or Frankfort black, made by burning the lees of wine (later Frankfort black was a fine grade of bone black); Brunswick black, made from asphalt; ivory black, etc. Bank-note printers had discovered that, of all the blacks applicable to the manufacture of plate inks, those resulting from the carbonization of ivory, animal bones, various kinds of wood, or mixtures of same, and especially of grape vines were most efficient.

How to vary the hue of black inks, and also obtain inks in various colors, was another problem. Steel plate printers added Prussian blue to develop the black without giving it a blue undertone, while etchers always used burnt umber or sienna to give warmth to the ink. The pigments used in plate inks should be of the lowest oil absorption.

As most intaglio plates are now of either copper or steel, it is necessary that the inks used in printing from them have not the slightest acid reaction on the metal plates. Colored plate inks, such as red and green, used in printing bank notes, postage stamps, bonds, certificates, etc., continue to be improved by frequent laboratory discoveries.

Today practically all modern steel and copper plate printers purchase their inks in ready-mixed form from manufacturers of printing ink. These manufacturers are usually equipped to meet the most discriminating requirements for intaglio printing, including plate inks for business and social stationery, as well as special inks necessary for die stamping from deeply engraved steel dies.

The use of appropriate inks, selected by the trained judgment of an artist to produce the most pleasing effects, makes the difference between just an ordinary print and an artistic result worthy of preservation.

CHAPTER XVII

LITHOGRAPHY, INCLUDING THE MODERN OFFSET PROCESS AND INK

IT is an interesting fact that the invention of the art of lithography, by Alois Senefelder, of Munich, Bavaria, about the year 1793, was not only accidental, but was made possible by special kinds of printing ink which Senefelder himself originated and manufactured. The patient and persistent manner in which the inventor of lithography pursued his investigation, often under most discouraging circumstances, is told by Senefelder in his own writings on the subject. All succeeding methods of planographic printing, including the modern offset press, are based upon Senefelder's remarkable discovery, the history of which is exceedingly interesting.

Lithography is an art that takes its place with dry point etching among the graphic arts for the reason that every touch of the artist's pencil or crayon on a lithographic stone is printed on paper just as the slightest scratch of the artist's needle on copper is shown in the dry point print. Lithography is a direct method by which an artist can express himself in duplicated copies of his original drawing.

Painting, water-color, pastel, pencil or crayon suffer with the disadvantage that these methods produce but a single copy, while the artist who turns his talent to drawing on lithographic stone can have his work reproduced in any color or number of colors he desires. It is unfortunate that comparatively few artists appreciate the art of lithography, for it is the most perfect medium for the reproduction of their handiwork.

The endeavors of young Senefelder to print copies of amateur plays he had written eventually led to the invention of lithography, and is a most fascinating story, an outline of which is given here:—

Alois' father, Peter Senefelder, was a court actor in Munich. Alois was born in Prague, November 6, 1771, and grew up with a longing for the stage. At the age of eighteen, he had written a play for his fellow students to produce in school. So well was this play thought of by those who read it that they suggested it be printed. Fortunately (for the art of printing) neither Alois nor his friends had the means to stand the expense of having it printed, for if they had, lithography might never have been invented.

The father of the playwright died when the son was twenty years old, so Alois was forced to give up school and he then decided to be an actor and playwright. He had already written several plays, but the cost of printing them was prohibitive, so he gave his whole mind to the thought of some method of printing them himself. He first thought of etching the letters intaglio, in steel and impressing them on pear wood so that the wood would be in relief and print after the manner of a type form. Then he practised writing in reverse so he could etch the letters in copper and have copper plate printers make copies of his work. But, he did not know how to make corrections in intaglio plates.

It was the grinding of the ink that at last led the way to printing from stone and it occurred in this way: He had turned to etching his letters intaglio on zinc and used a piece of Kellheimer stone as a muller for the ink. It occurred to him that this stone might be engraved and etched much easier than zinc and could be printed from just as well as from an engraved metal plate. So he obtained from a stone mason a thick piece of this stone, and after weeks of work in experimentation on the polishing and etching of it, he finally succeeded in printing from it, though the process was slower than from metal plates.

Senefelder then tells of a simple accident that resulted in his great discovery: His mother had asked him to write for her a laundry list, but having no paper at hand, he wrote the list upon the surface of a clean piece of Kellheimer stone, freshly polished. And, not having writing ink at the time, he wrote with printing ink composed of wax, soap and lampblack. Later, when he was about to clean the writing from the stone, he conceived the idea of etching it with nitric acid in such a way as to have the letters in relief and print from raised type. He found, however, that acid will not only etch *downward* but will also etch in *every direction* equally well, so he was compelled to stop the etching when he had but a slight depth. Believing there were some possibilities in this method, he then gave many weary months to build a press with wooden rollers to print from etched stone, but without complete success.

It was the ink he had discovered that would withstand the etching that Senefelder was most proud of at this time. He tells how he made at least a thousand experiments, until he thought one day why could not the stone be made to take a fatty ink while wetted parts of the stone would resist the ink? Acting upon this inspiration, he took a clean piece of Solenhofer limestone, which he found had a great affinity for fat. He drew on the stone with a piece of soap, poured over it a thin solution of gum, and rubbed over all a sponge saturated with an oil ink. All the places marked with the fatty soap retained the ink while the other parts of the stone remained white. He could make as many impressions as he pleased by simply repeating the operation. Thus was the art of lithography discovered years after Senefelder had written his mother's laundry list on stone, and his attempt to print from that stone.

Stone ink now began to engage Senefelder's attention, after he had secured a patent for his invention in England. He realized that so much depended on the ink, that he studied chemistry, and tells some of the ingredients used in experimentation, some of which are those used by lithographic ink manufacturers to this day. They were: common tallow soap; wax; tallow; butter and other animal fats; spermaceti; shellac; resins and Venetian turpentine; linseed oil; cocoa butter and resins, such as mastic, copal, dragon's blood and gum elemi. As solvents, besides the soap, he used vegetable alkalies, including tartaric acid, all the known mineral and animal alkalies, salammoniac and spirits of ammonia. He also tried borax and metallic solutions.

The first and most necessary material, says Senefelder, is the fatty or alkaline ink, as he calls it,—made of a mixture of fatty and resinous materials with an alkali, and is used to draw on the stone, or draw on paper and transfer to stone, or transfer from stone to stone. So important is the matter of a proper ink that Senefelder devotes pages of his "History of Lithography" to ink formulas.

For autographic ink he gives many formulas, the simplest being: White wax, 8 parts, soap, 2 parts, and lampblack, 1 part. This, after being mixed through heat, is rubbed up in rain water for writing with the same, as our modern tousche. He then gives formulas for a hard borax ink, a fluid ink, transfer inks, crayon inks, acid-proof inks, rubbing-up inks and printing inks.

Senefelder's intense study of chemistry proved necessary, otherwise he would never have succeeded in compounding the lithographic inks he perfected. How well he discovered the underlying principles in the manufacture of lithographic inks may be gathered from this paragraph of his writings: "Lampblack is not the only substance available for giving color to the ink. Vermilion, red chalk, indigo, blue lake of logwood, and several other colors can be used so long as they do not consist of acids or other salts, and thus possess properties that would alter the nature of the soap." He also calls attention to the fact that "lampblack usually contains a considerable quantity of wood acid which combining with the alkali would neutralize it and thus destroy its effectiveness with fats." To remedy this, he adds, "Lampblack can be purified by rubbing down with strong lye and then boiling in sufficient water to remove all trace of alkali."

Even as to the making of a superior quality lampblack, so necessary in lithographic inks, Senefelder goes into details. He recommends "that in order to obtain a superior article, lampblack should be made from ox or other animal fat; from wax; or better still, from a mixture of ox fat and resin. The fat is melted and poured into an earthen lamp, with a cotton wick. The lamp is lit and placed under a plate of metal or other smooth material so that the smoke must settle upon it. The plate must be close to the flame. The soot is scraped off from time to time and dropped into a glass which is kept covered. This process is continued, the lamp being refilled until the desired quantity is obtained. This soot is fine and soft, and so good that one can do more with an ounce of it than three ounces of the ordinary kind. The ink made from it is extraordinarily fine and good."

Senefelder repeatedly stresses the importance of good ink. He called his method "Chemical Printing" to distinguish it from typographic printing. Chemical knowledge being necessary in the compounding of lithographic inks, no lithographer or offset printer should neglect to read Senefelder's own account of his "Invention of Lithography" and particularly the chapters he gives to the making of different kinds of inks. Valuable knowledge would be gained regarding the principles underlying their art, and they would appreciate more fully the technical chemical knowledge involved in the ink manufacture of today to meet the increasing requirements of speed, drying, non-offsetting, etc. Were Senefelder living today, he would be overwhelmed with the color problems alone which the printing-ink manufacturer must solve.

During the last century many of the leading artists of the world took up lithography as a means of art expression. A list of their names would require a good sized volume. The French took it up with great enthusiasm and the exhibits of the work of M. Fantin-Latour, Eugene Isabey, Henry Daumier, Horace Vernet, Aubry, Gavarni, Baugniet, Lemercier, Courtois, Laurens, Lafosse, Rosa Bonheur, Delacroix, Doré, Decamps, J. F. Millet, Gericoult and Touissaint, are lithographic prints included among the most precious treasures in our art museums.

The most valued pictures in German homes often are the lithographs by Ludwig Wolf, Franz Leopold, Johann

Gottfield Niedlich, Gustav Kampmann, Franz Hoch, Fh. Hohe, J. Woelffle and hundreds of others. In religious pictures, which became the most popular in early years, to which lithography was applied, Germany easily led the world, so that the names of such artists as Hoffman, Defregger and Müller are known the world over.

English and Italian artists have immortalized themselves by lithographs, as well as have some American artists: The firm of Childs & Inman began printing artistic lithographs in Philadelphia in 1831, and since that time the United States has not been behind the rest of the world in artistic lithography. Among the American artists who have produced some of their finest work by lithography are F. O. C. Darley, Charles Hart, Louis Prang, Napoleon Sarony, Whistler, Joseph Pennell, Charles Parsons, Louis Maurer, J. E. Baker, H. A. Thomas, Albert Sterner, Bolton Brown, and many others. At the present time there is a revival of lithography among artists and we may expect new names among the distinguished exponents of this art.

When Daguerre, in 1839, showed the world that the image of the camera could be fixed on a silver plate, this discovery set lithographers thinking as to how the camera could be brought to their aid. Some of the best lithographers in the world began experimenting. They finally succeeded, and the result is a multiplicity of processes that it is difficult even to tabulate, and the end is by no means near. The first to bring out a reliable photo process was J. W. Osborne, in 1859. He made photolithographic transfers for transferring to stone. This process was used in New York City for the reproductions of steel engravings and government maps. In 1872 the Leggo Brothers brought to New York from Desbaret's lithographic plant in Montreal, Canada, a photolithographic method by which great quantities of lithographic work was produced, including an illustrated daily newspaper, called the *New York Daily Graphic*. Since then photolithography has become universal. Photolithography brought with it fresh problems for the ink manufacturer, both in transfer inks used and in lithographic inks.

Collotype is the English name given to the German method called *Lichtdruck* which gives the most beautiful results of the many planographic processes using the lithographic principle. It is not the invention of an individual but an evolution of the work of many experimenters. This method consists of printing from film of gelatine, that has a photographic image; the gelatine film having a supporting base of stone, glass or metal. Besides being the most delicate of printing processes, collotype requires a printing ink that is the highest achievement of the ink manufacturer's laboratory. The process of printing is a most sensitive one to weather changes, so that it must be carried on, to be successful, in a sort of artificial climate. Some of the most beautiful color printing has been done in Vienna in recent years with special inks, by this process.

The epoch-making revolution in lithographic history was the offset process first brought about by Ira W. Rubel, of Hackensack, N. J., through a missed impression on a press. At the time of his discovery he was using a smooth rubber blanket on the impression cylinder of a lithographic press which took the impression in the absence of the sheet of paper. When the next sheet of paper went through it was printed on both sides, and then Rubel noticed that the *offset* impression from the rubber blanket was in some respects better than the one direct from the stone. The result of this was the Rubel offset press, and now thousands of offset presses of various makes are in use throughout the world, although practically the same method has been used in the tin decorating industry for many years past.

As the offset presses are developed in both design and speed capacity, the questions of ink to meet the demands of the new presses are constantly changing. Among the advantages of the offset method of printing, besides the high speed obtained, are: its suitability for subjects of large size, such as posters; the soft edges and clear highlights it renders, and the fact that almost any kind of paper and fabric can be used to print upon successfully. It took some time for offset printers to learn that, though they might print on the cheapest kind of paper stock with good effects, success could only be had with ink made particularly for the offset process. A wide range of printed matter, including supplements for newspapers and magazines, is now being produced on offset presses, by the use of high quality ink made for the purpose.

The change in printing from a grained metal plate fastened around a cylinder from the cumbersome flat lithographic stone carried backward and forward in a flat-bed press, has brought the planographic principle of printing, which Senefelder gave us, to the point where it has become one of the leading methods of color printing, and one which undoubtedly has great possibilities for the future. All these changes are accompanied by demands upon the ink manufacturer for suitable inks to meet new conditions. This accounts for the expensive research laboratories which the leading ink manufacturers are obliged to maintain and which promise to be an increasing necessity. The experimental work in regard to inks for offset printing is due largely to the changes in manufacture of the papers for which the ink must have an adaptability in order to produce the magnificent results that are so much in evidence at the present day.

CHAPTER XVIII

PHOTO-ENGRAVING, HALFTONE, AND PROCESS COLOR INKS

AMONG the greatest and most useful inventions in the printing and publishing industry is the art of photo-engraving. This art, which had its beginning in France about the year 1813, when Joseph Nicéphore Niepce began his experiments with the camera obscura (invented by Porta about one hundred years previously), was eventually improved to a remarkable extent.

At the present time the photo-engraving method is being utilized in producing various kinds of printing plates, including halftones for single color printing, and "process" halftone plates for reproducing pictorial subjects in two, three or four colors. By this process it is possible to print reproductions of original drawings, oil paintings, water colors and pictures of any kind in their actual colors.

This great invention is in large measure responsible for the untold quantities of pictorial color work produced today on typographic printing presses. The vast majority of newspapers and magazines are illustrated by means of halftone engravings, printed either in a single color, or in two or more colors. Photo-engravings are also used for illustrating a great variety of printed matter, including book-plates, catalogues, brochures, booklets, and all kinds of advertising. It is a comparatively inexpensive method of printing reproductions of pictures, either in one color, or in a number of colors, and it enables every printer or publisher to produce pictorial printing, including the finest color work.

The story of the beginning of photo-engraving and its marvellous development is one of the most fascinating in the progress of the graphic arts. Joseph Nicéphore Niepce, an artist and scientist, was born in Châlon-sur-Saône in 1765.

About the year 1813 the then recently invented art of lithography, by Senefelder, attracted his attention, and for a time he studied the possibilities of this process, finally devoting his efforts to the making of photo-engravings and obtaining prints from them.

He had as a scientific toy a camera obscura, and wondered if it were possible in some way to fix permanently the image thrown on a screen by the lens of the camera. To do this he must first find a substance sensitive to the action of light, and eventually he found this substance to be asphalt. He took asphalt, added to it a proper solvent, then varnished a metal plate with it, and when dry, exposed the asphalt-coated metal plate to sunlight under the print of an engraving. The result was that the sunlight penetrated the paper between the black lines in the engraving and hardened the asphalt varnish. Where the asphalt was protected from the action of the sunlight it remained soluble in the original solvent. He dissolved away the unhardened asphalt, etched the metal with acid and then printed from this etched metal plate. The plate itself and prints from it are, with the rest of his apparatus, kept as precious treasures in the museum of his native town, Châlon-sur-Saône.

Niepce's quest was for a substance so sensitive to light that it could be used in the camera obscura, and asphalt was not sufficiently sensitive for this, although the British Museum has a number of asphalt-coated plates with faint camera-made images by Niepce. Consulting an optician about a faster working lens for the camera, Niepce learned that another Frenchman, Louis Jacques Daguerre, was experimenting with the same idea. Introductions were brought about and a partnership was formed. In 1839, six years after Niepce died, Daguerre gave to the world, with the help of the French government, a method of securing pictures in the camera which was given his name and called the "Daguerreotype." It was possible to make but one picture at a time by this method, and the process was very slow. Immediately scientific experimenters began work in an effort of finding a means by which the Daguerreotype could be utilized on printing presses and duplicates obtained in permanent printing ink. Just about this time electrotyping was discovered, but repeated attempts at printing from a Daguerreotype failed.

The year 1839 was an eventful one in the history of photography, for it was not until then that the Daguerreotype was made public, but Fox Talbot, of England, that same year announced a discovery for making photographs on paper. Also, during the year 1839 Mungo Ponton, of Edinburgh, announced through the Royal Society of London his discovery of the light-sensitive properties of bichromate of potash. It required several years before the value of Ponton's discovery was recognized in the world of art and science. Ponton himself did not realize what actually happened when paper was soaked in a chromate solution, dried and exposed to light. He thought the fibre of the paper was important. It remained for a Frenchman named Alphonse Poitevin to determine by experiment that it was not the paper fibre that was all-important, but the size, either albumen, gelatine or glue in the paper, combined with the chromate, that was sensitive to light, and that the action of light was to harden it and render it insoluble in water. Upon this discovery are based all photomechanical engraving and printing processes now in use.

Lithography, during the years 1840 to 1850, had come into general use in the reproduction of drawings of all kinds and the making of colored pictures, particularly religious subjects. Leading artists of the time applied their talents to drawing on stone, and consequently it was to lithography that the first application of Mungo Ponton's discovery was made. The first experiments in this direction were made by Dixon, in Jersey City, N. J., and by Lewis, in Dublin, Ireland, in 1841. Ten years later Lemercier, and others in Paris, and also MacPherson in England, took up Niepce's discovery of asphalt and applied it to sensitized lithographic stone in order thereby to get a print by photography that could be duplicated by the use of appropriate printing inks. Experiments were conducted in many countries at this period, all realizing that the first to invent the most practical process for utilizing light in the production of pictures on lithographic stone, or any other printing surface, so that the result could be duplicated in printing ink, would probably win fame and fortune.

As early as 1853 Fox Talbot practised the method of breaking up the surface of a printing plate by exposing the sensitized metal under an open mesh and then exposing this partially impressed plate under a negative. A similar expedient was later adopted by Berchtold in a process described before the French Photographic Society in 1859. Berchtold first exposed his sensitized metal plate under an ordinary negative, and then under a glass plate having finely ruled parallel lines, successively in criss-cross directions with gradually diminishing exposures, thus obtaining an effect analogous to a modern halftone plate. This same method, variously modified, was tried by Egloffstein, in Philadelphia, about 1861, and also by numerous other experimenters in America and abroad, but apart from Frederic E. Ives' (of Philadelphia) ingenious method of getting the result mechanically, no halftone process of practical value was evolved until 1882, when Meissenbach, of Munich, Bavaria, pointed the way.

Paul Pretsch, of Vienna, patented in 1854, a process based upon the reticulation of gelatine whereby the shadows in photographs could be broken into grain. This was a great step forward and brought the possibility of obtaining reproductions of pictures in printing ink much nearer. Pretsch established the Photo-Galvanotype Company in London, and within a few years was turning out relief printing blocks which could go into a letter-press with type. This method proved unreliable, however, one reason being that all photographic work is dependent on light, and at that time there was no powerful artificial light such as the electric light of today. In 1855, Poitevin, of Paris, took out a patent for making swelled gelatine relief plates and another patent for photolithography which he sold to Lemercier. Meanwhile, other experimenters in photo-engraving perfected swelled gelatine processes by various methods, including John Calvin Moss, of New York City, and Louis Edward Levy, who at that time was located in Baltimore. Between 1851 and 1872 Moss worked out a practical swelled gelatine process, and in 1875 Levy applied for a patent on a photo-electrotype method, the essential points of which were: swelling the exposed chrome gelatine film in silver nitrate solution; converting the silver chromate into amorphous metallic silver, and making this electrolytic by changing it into a sulphuret.

Among other notable photo-engravers who conducted experiments along the lines of Paul Pretsch's work were Matthew Carey Lea, of Philadelphia, and George Scamoni, of Russia. Concurrently, Avet, of Germany, was working a photo-electrotype process with washout gelatine; in England Waterhouse and James were etching zinc plates galvanically through prints obtained by photolithographic transfers; while in France, Gillot was making similar transfers to zinc and etching the plates by a "rolling-up" method which he had developed.

Cutting & Bradford, of Boston, took out a patent in 1858 for a photo-lithographic process, but it was John W. Osborne, of Melbourne, Australia, who patented in 1859 the first practical photo-lithographic method. He brought his process to Brooklyn, New York, in 1866, and it was worked for many years under the name of American Photolithographic Company.

It was the founding in New York City of The Graphic Company, in 1872, that gave perhaps the greatest impetus to methods of wedding the camera to the printing press. The process used was a photo-lithographic one devised by the Leggo Brothers, of Montreal, Canada. They left the Graphic Company in 1874 and carried their process with them. To advertise its business the Graphic Company, beginning March 4, 1873, issued an afternoon illustrated paper called the *New York Daily Graphic,* which continued for eighteen years until superseded by the daily papers using illustrations from relief plates. This contribution to the history of photo-engraving proved that photomechanical methods of producing illustrations were successful, as the paper appeared regularly with news of the previous day in illustrated form.

A further era in printing illustrations was marked on March 4, 1880, when the *New York Daily Graphic* showed the first pictorial illustration made from a photograph by Stephen H. Horgan, of New York, with his new technique and method.

Frederic E. Ives, the inventor who eventually put the halftone relief printing plate on a practical and commercial basis, displayed specimens of his first halftones in 1881, but almost at the same time similar specimens were exhibited by C. Petit, of Paris. Both inventors applied for patents simultaneously, and on account of "interference" by the Petit application, Mr. Ives failed to receive clear patent rights to his invention. By the year 1886 Ives had devised an improved method of making halftones through a cross-line screen, which method is still in practical use throughout the world today. Mr. Ives first published the idea of the "optical V-line," upon which the modern halftone is based, in a lecture at Franklin Institute, Philadelphia, in 1888, and explained the principles involved in producing it. But its application with the cross-line screen was then being held secret, and this secret was first publicly disclosed in a series of lectures delivered by Mr. Ives at the Bolt Court Technical School, London, in 1898.

In about the year 1880 began the decline of photolithography (as that process was then done) and the advancement of photo-engraving, or printing from relief plates. About 1868 a Frenchman named Charles Henry arrived in New York with a method of etching zinc plates in relief from a photolithograph transferred to zinc. In this he failed. Moss in the meantime had been experimenting with his photo-relief process: He coated a plate glass with bichromatized gelatine, made a photographic print on this gelatine from a line negative, swelled the gelatine print unhardened by light in water, took a cast from this in wax, then a mold in plaster, and the final printing plate was made in type-metal. In 1875 William Mumler, the so-called "Spirit Photographer," of Boston, obtained a patent for a photo-electrotype process. He printed on a thick film of bichromatized gelatine, as Moss did, but instead of swelling the unhardened gelatine, Mumler washed it away and made an electrotype from the hardened gelatine in relief. These were deep plates and were used in the reproduction of a foreign encyclopedia.

The zinc and copper plates from which relief printing is done today are etched plates, and the methods used in producing them are not the invention of any individual in particular, but an evolution of the discoveries of many experimenters. Bichromatized albumen has been generally used for sensitizing zinc. This was first worked out as a sensitizer on stone by Alphonse Poitevin, of Paris, in 1855, and required nearly twenty years before it was successfully applied to zinc. Gillot, of Paris, was very successful in etching zinc plates in relief, although he had trouble in protecting the sides of the relief lines from the undercutting action of the acid when etching. In Europe protection of the sides of the lines was had by "rolling up" the zinc plate after each etching with a soft, waxy ink, heating the zinc plates, and permitting the ink to melt and flow down over the sides of the etched line. This method was improved upon by Capt. A. J. Russell, of New York, who discovered in 1873 that the red rosin called "Dragon's Blood" when finely powdered could be brushed against the sides of the etched lines and by heat fixed there to protect the sides of the lines from etching, which is the method now in general use throughout the world.

It was Charles E. Purton, working in Philadelphia in 1883, who discovered that gum arabic and fish glue sensitized with a chromate, flowed on a copper plate, dried, exposed to light under a negative, the image developed by washing with water and then carbonizing the glue on the copper by subjecting it to intense heat, made a perfect acid resist. It was many years before this resist became generally known, though it is now used everywhere and on it depends the excellence of modern etched copper plates.

Following the advent of the first halftone plates, experiments with cross-line screens, for the making of halftones, were conducted by Louis and Max Levy, of Philadelphia, as well as by others in America and Europe These were photographic screens made on collodion plates. The use of bolting cloth, and both single and double-line screens, had been foreshadowed by many of the earlier photo-engravers, and in 1882 Meissenbach received a patent on the use of a screen in the camera to make halftones by optical means only. Growth of the photo-engraving industry was hampered, however, by the crude screens then available, and the kinds of paper stock then in use. With this fact in mind, Messrs. Levy turned their attention to the work of perfecting the halftone screen. Their success in this endeavor was remarkable. After the original ideas had been developed, Max Levy took over the business, and in 1893 patented a method of ruling and etching the lines for a screen in glass and filling in the interstices with a black pigment. The two pieces of glass for a screen, containing the ruled and etched lines, were then joined together at right angles with Canada balsam. This is the screen now used by all photo-engravers in the making of halftones.

The development of three and four-color process plates, for printing pictures in colors, was the crowning achievement in photo-engraving This also was due to the labors of a number of scientists. Louis Ducos du Huron in 1869 published a book entitled *Les Couleurs en Photographis* in which he unfolded the whole theory of the subject. Unfortunately, there were at that time no photographic plates which were sensitive to all colors, so du Huron died in poverty. Dr. H. W. Vogel made du Huron's theory practical by publishing in 1873 the principle that photographic plates could be made sensitive to colors by staining them with certain dyes, and that the same dyes be used in the colored printing ink when printing from the engraved plates.

The first practical process color work from halftones is said to have been accomplished by Ulrich, a lithographer of Berlin, Germany, who received a medal for results shown at London in 1891. Ives showed a number of three-color prints in 1885, but it remained for William Kurtz, a photographer and photo-engraver of New York City, to place three-color process printing on a commercial basis. In 1893 Kurtz exhibited beautiful specimens of color pictorial work produced from three-color process plates which had been made entirely by photography. *The Engraver and Printer* of Boston, in

March, 1893, published a reproduction of a variety of fruit with this title: "Photography in Colors. Taken from Nature by W. Kurtz, Madison Square, New York. Printed in Three Colors on a Steam Press." This was the beginning of three-color process printing which has since brought millions of dollars to the printing industry.

If present-day users of inks for three and four-color process printing could estimate the cost of experiments made to perfect these inks by the pioneers of the three-color system, the sum would amount to a tremendous fortune. Much of the trouble photo-engravers have today is due to the impossibility of getting photographic plates which are up to theoretical requirements. It is a well-known fact that there are no standards in color-sensitive photographic plates. This is due to the "filters" through which colors are photographed; to the varying lights by which photographs are made to the lenses; to the time of exposure given, and to human eyes that are to judge the colors. Moreover, there is no standard hue for the paper on which the colors are to be printed. It has been customary for the makers of dry plates to blame the lack of standard results on printing inks, when the ink manufacturer can supply any hue of ink required—something he is constantly doing at great expense, and often unappreciated. The Photo-engravers' Association has found by experience of over a quarter century the hues of inks best adapted for printing process color plates, and these have been adopted as possible standards, although changes must naturally be made to meet the demands of press speeds, the nature of the subjects reproduced, and above all, the character and tint of the paper on which plates are to be printed.

The Report of the American Photo-engravers' Association (twenty-fourth Annual Report, June, 1920) on the question of a proposed standardization of process color printing inks expresses the engravers' viewpoint so clearly in this matter that a few sentences from that report are illuminating: "Scientists tell us that there are just three colors which we can use, but most of them, who claim to be inventors with knowledge of these processes, do not agree as to just what those three colors are. Then the methods of how plates are produced vary in nearly every instance; no two engraving houses use exactly the same lenses, color filters or photographic plates, and consequently the inks that would answer in one case would not do at all for another. Thus it would not only be impossible, but unwise and unadvisable, to set a standard for process color inks by mere theory, without being able to standardize all methods, materials and instruments used in the production of the printing plates."

This report continues: "We should select for the yellow a color which contains no red—or as little red as possible—for if it does contain red, the red plate will require a great deal more etching, particularly in greens. Hence we should use as nearly as possible a pure lemon yellow, for we can easily warm it where required with a tone in the red plate. The red ink should contain no yellow, for otherwise it would be difficult to produce pink or purples. The blue should be free from red, or as nearly as possible. This will tend to reduce the work on the red plate. We all know that the red plate is the trouble maker. Dyes which will perfectly sensitize the red negative for greens and blues are not yet available. The yellow and blue should contain no red; this will help to make the red plate easier." The report offers as standards two shades of yellow, one red and two blues to cover every possible requirement of the process color engraver and printer, and all of which colors the modern printing ink manufacturer can supply on demand.

Considering the question of the paper stock on which process color work is to be printed, this alone is one of the difficult problems confronting the modern photo-engraver, as well as the ink manufacturer. It had been customary for photo-engravers to pull the "progressive proofs" of color plates on the finest enamel coated paper. This enamel coating was usually a blue white. The advantages were that it showed at once whether any dots were missing in the halftones, and only the absolute surface of the engraving printed. Besides this, it gave a brilliancy to the inks because they laid entirely on the enamel surface and the greens were usually of just the right hue and the purples and violets perfect. When the same halftones were printed on the regular stock, where the paper absorbed the ink and where the stock was of a cream tint, the greens and the violets suffered; the reds appeared stronger and not only the surface of the dots but their *sides* also printed to an extent. But above all these differences, the color inks used on the power press were from fifty to seventy per cent cheaper than those used in pulling the "progressive proofs." All this is now being changed. The largest printers of illustrations in color have their color plates proved up in the inks they use and on the regular paper the plates are to be printed upon. This is as it should be, for it relieves the photo-engraver, the ink-maker and the printer from criticism on the final result.

Even with all the above mentioned precautions, other factors enter into the color printing problem, and the principal ones among these are temperature and humidity, both in the making of the paper and in the pressroom during the printing. It is practically impossible to maintain a paper standard in its hue or power of ink absorption, and humidity in the pressroom makes a great difference in the manner in which ink lays on the paper, as temperature affects the consistency and flow of ink in the fountain. So important are these matters of temperature and humidity that progressive printing and publishing firms now use air-conditioning appliances in their pressrooms to regulate these influences on good color printing. The superiority and uniformity of the work produced, together with the saving in spoiled copies, more than repay the cost of such installation, besides making a healthier atmosphere for the workmen.

It is particularly important that the humidity of the pressroom be equalized during the entire year when what is called "wet printing" is being produced. When we understand that the reason ink leaves the engraved plate and transfers to the paper is because the affinity or adhesion of the ink for the paper is greater than its affinity for the engraving, we can realize what a revolution in ink-making occurred when the change was made from printing on damp paper to printing on dry paper. It is well known that paper somewhat dampened, with its fibres slightly separated through dampening, will take ink much better than paper not dampened. It was the halftone engraving that was responsible for this change. The halftone brought about the use of coated paper, and coated paper, of course, cannot be dampened for printing.

Now the demands of high-speed rotary presses often call for "wet printing," a method which means that the inks must be immediately printed on top of each other, when two, three or four colors are used, at a speed of over one hundred impressions per minute. This has brought new problems for both engraver and ink manufacturer, for it is practically impossible to find two colors that will work identically when printed wet and when printed dry. "Wet color printing" is now being done successfully because the engraver no longer leaves any solids in any of the process plates; the first plate when printed leaves everywhere some of the paper unprinted for the ink from the second printing plate to adhere to, and so on with the second, third and fourth process plates. The ink manufacturer has also made "wet printing" possible by providing inks with less and less cohesion in the order in which they are printed.

The demand is for greater speed in both engraving and printing, with the possibility of daily newspapers being printed in colors, so that engravers, ink makers and printers have even greater problems ahead of them than those which they have so far solved.

CHAPTER XIX

HISTORY AND PROGRESS OF ROTARY INTAGLIO PRINTING INKS

ROTARY intaglio printing, like plate or photogravure printing, is carried out by first applying the ink over the entire cylinder and then wiping it from the surface, allowing it to remain in the engraved portions. The paper is next applied and by its porosity draws the ink from the engraved design, thus differing from lithography (plane surface printing) or typography (raised surface printing) in principle.

Rotary intaglio is essentially a development from the plate process of printing bonds, steel engravings, etc., described in the preceding chapter. The old method of reproduction from engraved or etched lines in flat plates gives the most beautiful results and is still used for the highest types of printing. However, it is not suitable for newspaper or commercial work in general, due to its slow and tedious method of operation.

It was seen, therefore, in its development that if some method of speeding up the operation were devised, the length of time required, as well as the cost, could be reduced, and the excellent qualities of the print approaching the perfection of photography would really become a commercial possibility. The obvious way to accomplish this was the same as used in any other method of printing, such as typography or lithography, that is, to print from cylindrical plates on rotary presses, permitting greatly increased speed. Thus rotary gravure superseded the old plate or photogravure process for rapid printing of fine illustrations.

The rotary intaglio process dates back to the fifteenth century and is really a refinement of the textile printing process through the earlier process of photogravure, as outlined above. According to some of the most reliable authorities, rotary intaglio printing was done in about 1446 in Germany, and in the year 1452 by Finiguerra in Italy. The next development took place in England, where in 1785 Bell patented a process for printing textiles in six colors from engraved rollers, and in 1852 Charles Henry Fox Talbot took out English patent No. 565 for a method of manufacturing screens by means of a net or by ruled lines on glass. In 1865 English patent No. 1791 was granted to Joseph Wilson Swan for a screen which would form cells capable of holding ink.

Thus we see that while this process in general dates far back, the beginnings of photographic reproduction on paper at speed by this process were in 1894, when Karl Kleitsch (also spelled "Klic") came to England from Austria and interested Storey Brothers & Company of Lancaster. He is given credit by many authorities as being the originator of the rotary intaglio method of printing from etched copper cylinders and the inventor of the bitumen-grain gravure for photogravure.

In the year 1895 the Rembrandt Intaglio Printing Company was founded and financed by Storey Brothers, a famous English publishing firm, and began production in Lancaster, England. In the beginning of its venture the company founded by Kleitsch followed what was called the "Rembrandt process" and for a number of years this process was devoted particularly to the reproduction of fine etchings, paintings and other subjects of the fine art group. In this work the Rembrandt Company was highly successful and the superior quality of its product soon became known in America and other parts of the world.

The same year, 1895, a patent which had a bearing on rotary intaglio printing, British patent No. 24303, was granted Alfred Haley and William Thomas Wilkinson, and from this time on improvements were numerous.

In 1897 Pickup & Kelley built a machine for printing gravure and articles were published in Penrose's *Annual* and Huson's *Photo Aquatint and Photogravure.* A description of the process was given in the September edition, 1897, of *Process Photogravure,* and in 1901 Penrose & Company, of London, and W. L. Colls, of Hammersmith, England, began experiments. But, while the Rembrandt Company and other English companies were experimenting with the development of "machine gravure," as it was then termed, Dr. Mertens was conducting similar experiments in Germany about the year 1902. It is now acknowledged that Dr. Mertens was the first to apply intaglio printing to newspaper illustrations, which he accomplished by sensitizing the cylinder directly and which was in reality printing from an inverted halftone. The *Freiburger Zeitung* of Freiburg, Germany, in its Easter edition of 1910 was the first newspaper to contain such pictorial matter. That edition was printed on a new type of rotary intaglio newspaper press which had been perfected by Dr. Mertens.

Previous to this, however, in the year 1905, The Van Dyck Gravure Company was already working the rotary intaglio process in the Parker Building, Fourth Avenue, New York City, and this company was the first in the

United States to apply this principle of printing to photographic reproductions on paper. This organization, like the Rembrandt Company of England, devoted its efforts solely to the reproduction of fine etchings, paintings and the like. About this time many small plants were secretly entering the field, for example, The Henry Company, and the Mezzo-Gravure Company, but all of these were short lived.

Before the year 1909 many plants in addition to those mentioned above were working on this process. Among these were: Theodore Reich in London and later in Munich; Herbert Brothers in Willesden, London, and later in Budapest; W. T. Wilkinson in Wakefield and London; Orford Smith, Ltd., St. Albans; and Lascelles & Co., London.

In the year 1909 United States patents (No. 923799 and No. 935612) were granted to Charles W. Saalburg relative to this process, and in 1910 the Butterick Publishing Company began experiments with four-color gravure and some progress was made.

In 1912 the National Cash Register Company at Dayton, Ohio, installed a Mertens press for the publication of their weekly magazine, the *NCR Weekly,* but the Mertens process was more or less unsatisfactory both here and abroad, since the results were not of so fine quality as those obtained by a true process, in distinction to his inverted halftone process. About this time a small concern in Philadelphia, the American Gravure Company, was doing some printing, but little is known of its work.

The next development worthy of note was that of Merioni of France, who published the weekly magazine *Je Sais Tout* in 1911 and 1912.

In 1912 the *London Illustrated News* in London, and the *Hamburger Fremdenblatt* in Hamburg, Germany, began printing, the process steadily becoming better and easier of manipulation. The *London Illustrated News* was the first magazine in Great Britain known to have installed a complete rotary intaglio plant. The first edition of this magazine containing a gravure supplement was published in October, 1912. Every week thereafter the *News* contained a number of pictorial pages printed by the gravure method, the quality of which was so excellent that it soon attracted the attention of publishers in various parts of the world.

This process as applied to newspaper printing developed more slowly than in the fine arts field. As before mentioned, the first newspaper was the *Freiburger Zeitung* in 1910, followed by the *Hamburger Fremdenblatt* and the *Southend Standard* about 1912, the latter being the first newspaper in England to utilize the process. This was printed at Southend, a town about twenty-five miles from London on the Thames estuary. The R. Hoe & Company's London works built for the Standard Company an intaglio attachment which was used weekly for several years to print a full page of intaglio pictures, the type being applied from stereotype plates. The reverse side of the sheet was printed in the usual way on a regular press. The process and equipment for the gravure work were furnished by Penrose & Company, London.

It was about this time that the American newspaper readers received their first introduction to the pictorial gravure supplement, now one of the most attractive features of practically all Sunday papers of importance. The New York Times has the credit of introducing this feature in its Christmas edition of 1912. The entire edition was printed for them by the Sackett & Wilhelms Corporation, who had secured the American rights to the Rotogravure Process developed by a combination of German printing plants. The word "rotogravure" is said to have been coined by these German plants as a result of the consolidation of the Rotophot Company of Berlin and the Photogravure Company of Siegburg.

The response was so favorable that the *New York Times* at once ordered three presses of the same type and shortly thereafter this supplement became an established weekly feature.

During the next few years the rotary intaglio process spread rapidly throughout America. Three or four of the largest newspapers installed complete gravure plants, and in New York City and other cities of the United States various companies installed the same type of equipment to be used in the production of newspaper and magazine supplements, inserts for mail order catalogues, advertising literature and the like.

With the advent of the World War, however, the development of this class of business was seriously interrupted and essential supplies from abroad were cut off. This interruption, however, proved a real benefit inasmuch as it forced each country to independent development and, as events have since proven, the future for it was to be more promising than ever.

During the period of the World War experts were at work in America, England, Germany, France and other countries studying the future possibilities of the process and perfecting new styles of presses for its production. At the same time progressive manufacturers of paper, ink and other materials used were actively engaged in perfecting their products.

Thus, as the years passed on, almost everything that had to do with the rotary intaglio process was in course of evolution and at the close of the war the entire process was ready for a more extensive use.

A typical procedure of carrying out this process, as used in a modern newspaper plant, is as follows:

The art department receives the copy from the news agency or advertiser and makes up the form and general layout of the page, scaling the copy to correct size, and this is sent to the photographic department, where continuous-tone negatives are made to the proper size, which are retouched if necessary. From these negatives, positives are then made and these again retouched. The positives are then made up into page form by pasting on a glass plate or film.

This is called the layout and is used to get the image on the carbon tissue in a manner similar to that used in making prints from an ordinary photographic plate, by means of a vacuum printing frame. This carbon paper is a special grade of paper, coated with a gelatine mixture, the solubility of which, when sensitized with bichromate of potash, is affected in proportion to the amount of light reaching it. More light is admitted through the high lights, which tends to make the gelatine firmer and less soluble; while the deeper the shadows, the less light admitted, and the more soluble the gelatine.

After the positive layout is printed on the paper, the paper is exposed a second time to the light through a special gravure screen, which consists of a large number of very fine crossed lines, ruled on glass. These quite often form as many as 22,500 squares to the square inch and eventually form the ink-holding cells in the cylinder. The prepared carbon tissue is then squeegeed to the copper cylinder, which is then rotated in warm water until all the gelatine unaffected by light has been completely washed off, leaving on the surface of the copper varying depths of the light-hardened gelatine in proportion to the graduation of tone in the positive. This light-hardened gelatine is dried on the cylinder, forming a resist for the etching fluid and the cylinder is then ready for the "staging" operation. This operation consists in painting out all portions not to be etched with an asphaltum varnish, which absolutely bars any acid from affecting the portions of the cylinder so treated.

The cylinder is then ready for etching. This may be accomplished either by flooding the cylinder with acid or by painting with cotton soaked in the acid. The "acid" used is perchloride of iron, which must be specially prepared for this purpose. Etching is begun with the most concentrated and heaviest acid, because this acid has less effect on the gelatine tissue than that containing a greater percentage of water, and goes though the thinnest film of gelatine first, etching the shadows. Progressively weaker solutions of acid are used until the high lights begin to appear, when the operation is stopped and water is poured over the entire surface to wash away all traces of the etching fluid. The remainder of the gelatine film is removed by acetic acid or other such material. The cylinder is then cleaned of all gelatine and asphaltum varnish "staging" and when dried is ready for the press.

A basic difference between the gravure and halftone (relief) processes is apparent by examination of the two surfaces through a magnifying glass. The gravure engraving consists of minute square depressions, all of uniform area but of varying depths, thereby producing the various tones on the printed sheet by the application of thicker or thinner layers of ink. On the other hand, the halftone process accomplishes its variation in tone by the larger or smaller area of the ink spots, the thickness of the ink applied being uniform.

Each cell is surrounded by a thin wall of copper, which is smooth on its surface. These walls of copper are to act as "bearers" for the ductor, or "doctor," a thin flexible blade of steel which not only wipes the ink off the etched part of the cylinder (leaving the ink-holding cells full), but entirely removes it from the plain surfaces where the plate is not etched, thus leaving clean margins on the printed sheets.

The rotary intaglio perfecting press, when built for newspaper work, is composed of two pair of cylinders, or printing sections, as they are called, together with a folding mechanism such as is used on either regular rotary newspaper or magazine presses. One of the cylinders in each pair is called the "copper design cylinder," into which the illustrations and other matter to be printed are etched. The other is known as the "impression cylinder" and is in reality a steel core covered with vulcanized rubber. The paper is fed from a large roll, usually placed between the two press sections, and is led through one pair of cylinders, where it is printed on one side, and then over a drying drum to the second pair, to be printed on the reverse side, or "perfected," as this operation is termed. From this point it continues over still another drying drum, there being one for each press section, and is then cut and folded to newspaper of tabloid size. These products are delivered from the folder on to an endless belt arrangement, finished and ready for distribution. The drying drums are heated by steam or electricity, and their function is to dry the ink before it can be smutted by coming in contact with other rollers and cylinders. The lower part of each design cylinder revolves in a fountain of ink that is located directly below it.

In recent years a number of different makes of rotary intaglio presses have been perfected and placed on the market, including new types of sheet-fed rotary presses, which have made close-register color printing by the intaglio method practical. At the present time a considerable number of sheet-fed rotary presses are being used with remarkable results in America, England, Germany and France. The quality of the multi-color pictorial work produced on these machines is gradually being raised to a higher standard.

In addition to sheet-fed presses, great strides are now being made in multi-color work on web presses as supplements to a number of the great American newspapers, among them the *Chicago Tribune*.

The *New York World* is using a process, the pictorial subjects incorporating the most delicate tints. An entire supplement to this paper is printed by the gravure or intaglio method. From recent notable examples of "process" intaglio printing, it seems reasonable to believe that this class of pictorial color work bids fair to be developed on a much larger scale in the near future.

Speaking on the subject of multi-color work, as done on rotary intaglio presses, Charles F. Hart, expert in newspaper color printing, of New York City, expresses the following opinion:

"Every indication, based on color gravure experiments, points to the ultimate success of fast running color printing at a low cost to be a combination of three color offset and one KEY color of gravure. The results obtained from this combination are very remarkable. It can be very easily run up to a speed of 5,000 or 6,000 impressions per hour, but it necessitates a specially designed press and method of drying so the product can be instantly folded for either newspaper or magazine work."

The making of special inks for rotary intaglio printing adds another chapter to the achievements of American printing ink manufacturers in their research laboratories, as an entirely new problem was presented for solution. In the first place, a fluid ink is required for rotary intaglio printing. This thin ink is essential to the printing process: first, because the thin ink readily fills the many thousands of cells in the etched copper cylinder; second, after the sheet has been printed, the small "dots" which form the shadows, intermediate tones and almost solid portions of each picture, amalgamate to a certain extent on account of the soft nature of the ink. The ink must also be adapted to high-speed printing, the large presses giving from 4,000 to 10,000 revolutions per hour, and it must dry rapidly without smutting. It must carry sufficient body to hold the pigment and bind it to the paper so that it will not smudge or rub off afterwards, and above all, it must dry in an incredibly short time. The reason for this rapidity in drying is due to the fact that after one side of the paper is printed the ink on it must be perfectly dry before the paper reaches the second cylinder of the press.

In ordinary relief printing, inks contain certain metallic bases and salts that are known to have the property of accelerating the drying of the ink when spread upon paper. The inks used on web presses running at very high speed came nearer being the kind of ink for use on rotary intaglio presses than any other, but these were soon found unpractical, and modifications were unsuccessful.

When aniline dyes are precipitated upon metallic bases the results are called "lakes" and are commonly used for colored inks. They are usually far more stable, so far as permanency to light is concerned, than the original dyes from which they are made. Much work was done in precipitating coal-tar derivatives on zinc, lead and aluminum bases in the hope of discovering proper pigments for these rotary intaglio inks.

Another difficulty arose which had not manifested itself in web press inks. A single particle of grit of any kind getting between the copper cylinder and the "doctor," or steel scraper blade, would permanently scratch the soft copper surface of the cylinder. It was a common thing to see fine lines of ink, due to such scratches, in the gravure supplements of various newspapers during the years when the preparation of these inks was largely experimental.

The varnish or binding medium also presented a difficult problem, but the patient researches of chemists were at last rewarded when they turned to the use of asphalt. Asphalt itself was tried, then ozokerite and the different mineral waxes, when eventually an ideal substance was found in gilsonite. This is a hydrocarbon called "Uintaite," found only in the United States in a belt about 65 miles long, extending from Colorado into Utah, the most important veins being in the latter state. A valuable feature of gilsonite is that it melts at a rather high temperature, 250 to 350 degrees Fahrenheit, and is soluble in gasoline, xylol and the more volatile constituents of mineral oils. It is the principal binder used in the manufacture of brown and black intaglio inks. Its color, however, renders it absolutely unfit for use in bright blues, violets, reds, yellows, etc. In this latter class of inks the binder may be a resinous substance such as rosin or several of the varieties of gums from East India. Gilsonite has solved the problem of rotary intaglio ink to a large extent and in a most satisfactory manner. It is mined and sorted into two grades called "firsts" and "seconds," and shipped to market in large jute bags. Unaffected by rain, snow, frost or summer heat, it can be exposed to the elements without injury.

The ink for rotary intaglio printing can be made in any color desired. Past demands have been principally for shades of brown, though the present tendency is to a greater variety of colors, such as blues, green, reds, oranges, etc.

Many fields for which rotary gravure is so admirably adapted have barely been explored and the future of this process is indeed very promising. Its fine detail, delicate tints and soft effects give a depth of printing that can be obtained by no other process except the expensive production of mezzotints and etchings by hand work.

CHAPTER XX

PRESENT-DAY METHODS OF INK-MAKING

IT is a well-known historical fact that early typographic printers used only two colors of ink—black and vermilion—in producing their now famous Bibles and other books. Almost all this work was printed entirely in black ink, but some of the more notable books printed from forms of movable type were illuminated with vermilion ink. What is now believed to be the first book having a printed date (1457) is the splendid "Psalter," which is also said to be the first book printed in two colors, black and vermilion.

Today, however, so many different kinds and colors of printing ink are used throughout the printing and publishing trades that it would be impossible to compile a complete list. New printing processes are evolved, other processes are gradually developed to higher perfection, and to provide for the special requirements of these processes, different inks must be made. As time advances entirely new uses for printing ink are discovered, so that the manufacturer of printing ink must be ever on the alert to supply any special grade or color of ink required. "Eternal vigilance is the price" that every progressive printing ink manufacturing firm must pay if it is to adequately and constantly meet the exact demands of the printing trades.

The so-called "process" color printing will serve as an example to show how the printing-ink industry was called upon to supply typographic printers with the special inks and colors particularly adapted to such work. Following that development came the comparatively new processes called "offset printing" and "rotary intaglio printing"—two entirely different methods, each calling for inks made exclusively for its purpose. The introduction of high-speed rotary presses in the magazine publishing field brought other demands for special inks (both black and colored) adapted to high-speed printing done on presses of this class. Other examples could also be cited.

The more important printing inks regularly used in the printing industry are:

Black Inks for Typographic Printing. The term "typographic printing" applies to relief printing in general, and a large variety of black inks are essential to provide the many requirements of typographic printers. Among the more common of these blacks are the following:

Black Book Ink: A high grade black book ink is made from carbon black and pure linseed oil varnish, or its equivalent. The carbon black used is obtained solely from the burning of natural gas and in tinctorial strength is superior to any other black pigment. This ink is used for the printing of books, magazines, trade journals, etc. Lampblack also finds application in this type of ink, but to a limited extent.

Black Halftone Ink: An ink made with rather a soft body essential to the printing of halftone plates on coated paper, enamelled paper, or other smoothly finished stocks. Were a halftone ink made with a heavy body, it would have a tendency to "pick," or "lift," the surface of coated, plated or enamel paper during the printing operation. The best quality halftone black is formed of the finest carbon (gas) black and pure linseed oil varnish, the mass being ground exceedingly fine and soft. Not only may this ink be used for printing halftones exclusively, but also in printing forms consisting of both type matter and halftones. It is also suitable for printing lines engravings, wood engravings and solid plates having lettering or other detail cut out.

Job Black: An ink having a somewhat heavy body, of a quick drying nature, for general job work and commercial printing, such as business cards, factory forms, business stationery, circulars and miscellaneous advertising. The highest grade job black is carefully compounded so it may be worked on different kinds of paper and even cardboard with efficient results.

Bond Black: A heavy bodied ink, sufficient tacky to print well on all papers of the bond, ledger and writing variety. This kind of ink is intended only for printing on bond, ledger and writing papers, but may also be utilized for printing on certain kinds of cover stock.

Newspaper Black: News ink is now manufactured especially for use on high-speed rotary newspaper presses and of course must be made at low cost on account of the vast quantities consumed by the great daily newspapers. Ink of this character is generally made of the common grade of carbon black and a special "news ink varnish," obtained by dissolving rosin in mineral oil. For some purposes a small part of oil-soluble blue dye, or its equivalent, is added to give news ink the desired undertone. News ink of this character is adapted to printing coarse-screen halftone plates on news stock as well as printing the type sections of stereotype plates for newspapers.

Colored Inks for Typographic Printing. The use of color printing has increased so rapidly in the last decade that it has now become necessary for printing-ink manufacturers to produce a wide assortment of colored printing inks. Special colored inks are manufactured for different classes of color printing, such as two, three and four color process work; multi-color printing; combination halftone and line engraving color work; color printing from solid plates; and for letter-press color work of the variety done from type forms.

Process color printing (from halftone plates) has become one of the most important branches of the typographic printing industry. This process is employed by the majority of commercial printers in the production of advertising literature, pictorial catalogues, souvenir booklets and other color pictorial work. The same process is now used by the larger magazine publishers for pictorial magazine covers and for full-page and "double-spread" display advertising pages in magazines. In 1914 only about one percent of national magazine advertising was in color; since then it has increased more than thirty percent according to reliable estimates of publishers.

Special process color inks are made for "wet" printing in two, three or four colors. These specially prepared inks are in addition to the regular process colors made for "dry" printing.

The term "wet" process printing applies to two, three and four color halftone pictorial work produced on flat-bed cylinder presses, rotary web presses, and sheet-fed rotary presses of special design. On a two-color model of a flat-bed cylinder press, two colors may be printed as a continuous operation by the "wet" method. On a web press of the magazine type, two colors may also be printed as a continuous operation.

A LABORATORY IN A MODERN PRINTING INK FACTORY

Taking four-color process work as an example, on a sheet-fed rotary press the "wet" printing is accomplished as follows: The regular order of colors is yellow, red, blue and black, but some printers prefer printing the black first and then follow with a transparent yellow. In any event, the first color is mixed so that it will be rather "stiff" or tacky; the second color is made less tacky; the third color is still softer; and the final color is the least tacky of all. By this method of mixing the inks it is practicable to print one color over another immediately and at a high rate of speed. A very large number of four-color pictorial pages appearing in the national magazines are produced by this method.

The "dry" process consists of printing one color at a time and then allowing the sheets to dry somewhat before printing the next color. As a matter of fact, the printing of the first three colors for a four-color job should not be absolutely dry before the last color is applied, as this method will permit of a more perfect amalgamation of the various films of color. Moreover, if the first, second and third colors are exceedingly dry on the paper before the last color is printed, it will be a difficult proposition to have the last color "take" properly over the surface of the others. The ink in this case is said to "crystallize."

Process Color Inks. These inks are made exclusively for the purpose of printing pictorial subjects, reproductions of original paintings, etc., in colors from halftone plates. It is important to note that the so-called "process color printing" is now being done in two colors, three colors, four colors and to some extent in five colors. Special process inks are made for this class of printing and to provide for the printing of pictures in any number of colors desired. The larger ink manufacturers can supply on order various shades and kinds of process colored ink, in the proper combination of colors and working body, to match any engraver's set of progressive proofs. In actual pressroom practice, however, it is not always possible to perfectly match the colors on an engravers' set of progressive proofs for the reason that such proofs often contain thick films of ink which could not be duplicated on high-speed rotary presses. Because of the great speed in the production of process color printing in large magazine plants, it is necessary to "cut down" the flow of color rather than to run thick films of it. Under these conditions, it is sometimes a mechanical impossibility to perfectly match the colors on many original proofs.

Inks for Multi-Color Printing. Multi-color printing is somewhat different than process color work, as the plates generally used for this class of printing are either line engravings or a combination of solid parts and line engravings. Also, in many instances the plates used may be combinations of halftones and line engravings. Special colored inks are necessary for the particular kind of multi-color printing to be done. In some cases these inks are to be transparent colors while in other cases the colors should be semi-transparent or even opaque.

The term "transparent," as used, indicates that when two or more transparent colors are superimposed, the under color will have an influence upon the tone or shade of the color printed over it, and *vice versa.* This effect is desirable for certain varieties of multi-color work, especially those incorporating solid portions of plates. A multi-color job may be printed in from two to ten colors to obtain the desired finished result and in numerous instances the plates may call for the use of *tinted* inks in addition to regular colors, like red, blue, yellow, orange, green, brown, etc.

Semi-transparent colored inks are frequently employed in printing multi-color pictorial subjects from combination halftones and line engravings. Opaque inks are usually required for multi-color work on cover stock or on colored or tinted paper stock of any kind, for the reason that the color of the stock would influence the color of transparent or semi-transparent inks.

Duplex Color Inks. These inks, also known by other trade names, are made for printing halftone plates in single color. Duplex color inks "automatically" cause the printed picture to take on several different tones of the color used. They are made in the standard colors, such as sepia, photo-brown, photo-green, photo-blue and so forth. This kind of ink is generally made of a stable halftone ink with the addition of a small quantity of fugitive oil soluble dye. The purpose of adding this dye is to obtain a thin circle, or halo, in a different shade of the color used, around each halftone dot on a print.

By this method the finished print, when dry, has the appearance of double printing. Using certain colors of duplex ink and tinted paper, the screen, or halftone dots, on a finished print are made almost invisible. For example, when a fine-screen halftone plate is printed in sepia duplex ink on India tint coated paper, the halos around the halftone dots eliminate to a great extent the "white spaces" between the dots, and this unique process, combined with the color of the India tint stock, causes the print to have a beautiful solid-tone appearance. Duplex inks are made in any color or shade desired and to work on any grade of coated, enamelled or plated paper.

Colored Inks for General Typographic Printing. Inks of this group are made in all the standard colors. They are of an opaque quality which is necessary to print forms of type in color, labels, cover designs and job and commercial work in general. The tints can be furnished in either transparent or opaque according to one's preference.

The "standard" colors, like red, blue, yellow, orange, green, brown, etc., are made in various shades, some of the better-known names being: lemon yellow, chrome yellow, vermilion red, Indian red, Prussian blue, bronze blue, chrome green, lake red, bronze green and scarlet lake. Red and blue inks are made in more tones and shades than any other color, and in this connection it may be well to note that every printing-ink manufacturer has his own standards for colors. There is really no universal "standard" red, blue, green or other color.

White Inks for Typographic Printing. A number of different kinds of white ink are regularly used in the printing trade, including special cover white, flake white, magnesia transparent white and aluminum flake white. Cover white is usually of an opaque quality especially adapted to printing on cover stock, cloth book covers, photograph mounts, etc. Transparent white is sometimes used for mixing special tints which are to "over-print" a darker color. The regular mixing white is opaque and is often employed in compounding special tints and colors.

Although it has long been a practice of pressmen to mix special tints and colors with white, the modern method is to have the ink manufacturer attend to this. When placing an order for a special color or tint, the printer submits a sample of the printed color to be matched and also a sheet of the paper stock on which it is to be run.

Cover Inks. These are opaque, heavy bodied inks of many hues, ready for use in the pressroom in printing colored or tinted cover stock, also for printing cloth covers for bound books. As a general rule, an ink of this character is made to dry with a solid appearance and a high gloss.

Gold, Silver and Aluminum Inks. These inks are usually supplied in mixed form, ready for immediate use in the pressroom, and in this form give fairly satisfactory results. However, for exceptionally fine printing the ink manufacturer generally supplies a separate liquid (or size) and bronze powder, which are mixed by the pressman when he is about to print a job. This method is proving highly successful throughout the industry and a wide range of work is now being printed in gold, silver or aluminum, comparing well with the sized, powdered and dusted product in the old-fashioned manner. The most successful results in printing with gold, silver or aluminum ink are obtained by using a glazed or polished paper.

Size for Bronzing and Gold-leafing. While it is true that large quantities of gold, silver and aluminum inks are used in printing glazed labels, paper box wrappers, and other work adapted to the use of such ink, it is likewise a fact that much printed matter is still produced by the bronze-powder method. Other classes of work are first printed in size after which the gold-leaf, silver-leaf or aluminum-leaf is laid over the freshly-printed form to be finished.

These two processes call for the use of special size similar to a tacky "yellow" or "yellow-brown" printing ink. One grade of size is made expressly for bronzing and another for gold, silver or aluminum leaf-laying.

Copying Printing Inks. Copying inks, though having formerly had a more extensive use, especially among railroads, banks and insurance firms, are still used for printing special forms of a character where it is necessary to take complete copies, including the printed matter and writing, to be kept on file as records. A good grade of copying ink is composed of glycerine of the standard 1.260 specific gravity, a special syrup to aid in holding this gravity, and the essential dye. The colors most used are: black, blue, green, brown, dark red, brilliant scarlet and purple.

Check Safety Printing Inks. Though not identically the same, these inks are somewhat similar to copying inks. Like the latter, they must be absolutely free from oil and are usually made of glycerine of the same specific gravity, but to prevent deterioration from moisture (which would spoil the working body of the ink) the proper proportion of a syrup of the opposite tendency must be added. Both check and copying inks are colored with similar dyes to produce a variety of colors. The check safety inks include tints of pink, yellow, buff and pale green. In the printing process the paper stock for checks is given an "all-over" pattern or background. Special check inks are made for typographic printing, for lithography and for the dry offset process. The practical purpose of these inks, of course, is to prevent changes or forgery.

Cancelling and Indelible Marking Inks. These inks, indispensable for certain purposes, form an important line of printing inks. A cancelling or marking ink must necessarily contain an indelible dye to prevent destruction or effacement. Cancelling ink is used in post offices all over the world for cancelling postage stamps and in government departments for cancelling tax stamps, etc. This ink is also used by typographic printers in the work of pre-cancelling sheets of stamps for large users. When postage stamps are thus pre-cancelled, time is saved both for the user and for the Post Office Department. Cancelling ink is invariably black, and when printed cannot be removed by chemicals or other means.

The indelible marking inks are made in black or any color desired, black, however, being the most practical color. Typographic printers use black indelible ink for imprinting marks or names on linen articles, towels, fabric novelties, etc. Marking inks are also largely used in laundries and by manufacturers of linen shirts, collars, cuffs and underwear, the marking being done after the manner of typographic printing on machines designed for the purpose.

Bookbinders' Cloth Inks. These inks are made particularly for printing titles or designs on cloth book covers and are mixed with an opaque pigment to avoid double printing. They differ from the regular cover inks (used for printing on paper cover stock) in that they are not made of linseed-oil varnish entirely, but contain a percentage of gum and a powerful gloss drier. These inks are made in black, white and all popular colors.

Label Inks. These inks are made in black and all standard colors to work on different grades of paper. Label inks are much like regular typographic inks except that they are often made inexpensively to provide for long runs of colored label work.

Poster Inks. Broadly speaking, the so-called "poster inks" used for printing bill posters, large-size theatre posters and other work of this variety, differ little from the cheaper grades of colored "job" inks. Some grades are made particularly for printing from solid wood engravings, wood type, etc., on common news-print paper. Other grades are of better quality, adaptable to the production of fine pictorial posters in two or more colors. Again, formulas can be modified to make it particularly suitable for the printing of illustrated newspaper supplements in color.

Special Letter Press Inks. In addition to the inks already mentioned, special printing inks in black, white, or any desired color, are made for printing on such materials as wood, glass, tin, celluloid, silk, leather, vellum, waxed paper, onion-skin paper, pressboard, linen, cotton cloth, aluminum, rubber, parchment and tin foil. A special ink of different compound is necessary for each of the different materials.

Carton Inks. A distinct and separate class of printing ink is that called "carton ink" in the paper box industry. Made in black and white and all standard colors, it is designed especially for printing paper board stock for cartons, folding boxes, display containers and similar lines.

Lithographic Inks. Three different classes of lithographic ink are now manufactured,—the first for lithography from stone; the second for printing by the rubber blanket offset method on paper and cardboard; the third for printing on tin or other sheet metal by the offset method.

As a rule, lithographers working on presses prefer ink of a heavier body than the average letter-press ink, which can then be reduced to the extent necessary for the job in hand. Lithographic ink is necessarily of a comparatively "greasy" nature so as not to be affected by the water-rollers employed on lithographic presses. This line of ink is manufactured in base white, flat white, black and in all the standard colors and tints. For multi-color work produced on a stone lithographic press, opaque or semi-transparent inks are generally used. For the modern method of process color work, special process colors in some respects like the process inks used in halftone color printing on typographic presses, are used.

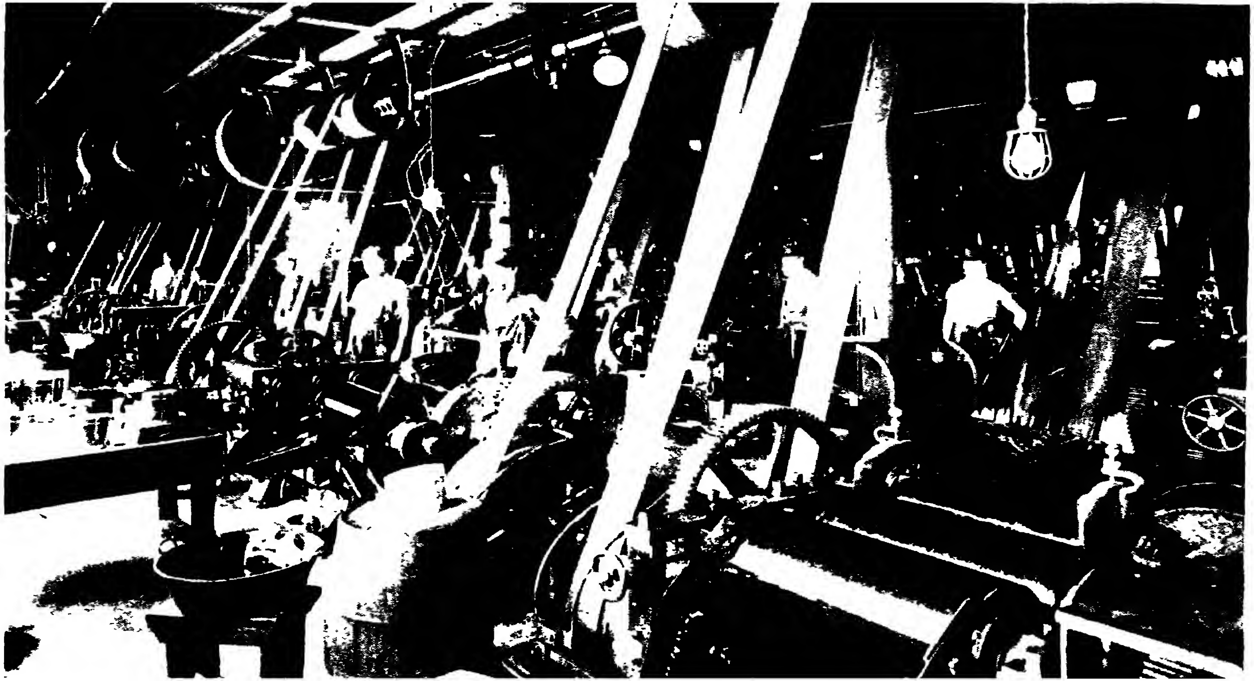
The offset process of printing—which bears rather a close relationship to stone lithography—has developed to a wonderful degree in recent years. Today, practically every class of "black" and color-work that can be done on a stone lithographic press can also be handled on a rubber blanket offset press, but special inks are needed to produce offset printing of the highest quality. These special inks are required for the reason that by the offset process the rubber blanket cylinder of the press accepts and transfers only a small amount of ink compared with stone lithography. The ink used in offset printing must possess the finest printing quality and contain no ingredient that would be injurious to the surface of the rubber blanket. Special offset inks are made for ordinary black and color printing, for multi-color work and for two, three and four color process work.

The highly perfected method of printing on tin or other sheet metal on an offset press involves a baking or stoving process by which it is necessary to bake the color on the sheets of metal (after printing) under a temperature of from 130 to 160 degrees F., and this baking process is continued for a period of several hours. The ink for offset printing on sheet metal must therefore be so compounded as to withstand the severe test of this heat treatment without showing cracks or discoloration.

Inks for Steel and Copper Plate Printing. The most important member of this group is known as "copper-plate black" and this same kind of black may be utilized both for steel plate printing and copper plate printing. A great deal of this printing is now done on power plate presses. Power plate presses of this type are also used in printing paper money, postage stamps, bonds, etc., from intaglio engraved steel plates. Inks for these purposes should possess the quality of lifting easily from the engraved detail of the plate when the impression is applied to paper, and at the same time should be of a consistency to permit the surplus ink to be wiped away cleanly from the surface of the engraved plate. The larger printing-ink manufacturers furnish a standard "copper plate black" that is made from the best carbon black and oil. This is not a quick drying ink and it dries with a soft, dull finish on the surface of the stock. The manufacturers also supply the same kind of ink in any color desired. The green and orange inks used in printing paper money are of a special quality that will withstand the hard and frequent handling to which paper money is subjected. Much the same kind of ink is made for printing the various colors of postage stamps and none dry with a gloss.

Inks for Steel Die-stamping. The inks generally used for steel die-stamping are different from plate-printing inks in that they are made to dry with a high gloss. This ink must be so formulated that it will lift perfectly from the deeply engraved die, yet it should wipe easily from the surface of the die. The high gloss is obtained by adding dammar or other gum varnish to the mixed ink.

Inks for Rotary Intaglio Printing. A complete line of rotary intaglio inks in all colors is now produced by all the leading manufacturers of printing ink. The most popular colors are sepia-brown, dark green and photo-



MODERN PRINTING INK GRINDING MACHINERY

blue. By the gravure process, the printing is done from an engraved copper roll containing finely etched cells. These cells are etched below the surface of the copper design cylinder and the ink used in the process must be soft enough to fill the cells as the design cylinder turns in the fountain of the press containing the ink. Before each printing, a "doctor" blade passes over the surface of the engraved cylinder and removes all ink with the exception of that remaining in the cells. Because of the high speed of the modern rotary intaglio press, the ink must dry on the paper more rapidly than the average ink used on the flat-bed press, a result which is accomplished to some extent by making the ink with a rectified white spirit. The heated drying drum (or drums) on a rotary intaglio press also hastens the drying process.

A finer quality gravure ink than that referred to is made particularly for pictorial art printing, portraits, reproductions of etchings, etc., as produced on sheet-fed rotary intaglio presses.

Collotype Inks. These inks are made exclusively for the collotype process of printing from a smooth gelatinized surface and are somewhat like soft lithographic inks of good quality, the printed results being exceedingly beautiful.

The larger printing-ink manufacturing firms are now supplying the entire printing world, including typographic printers, lithographers, steel and copper plate printers, offset printers, gravure printers and collotype printers, with inks, dry colors, varnishes, reducers, driers, etc. In other words, a large printing ink concern of the present time is so equipped that it is in a position to manufacture ink suitable for any method or process of printing, no matter what that method or process may be.

ETYMOLOGY

THE derivation of the English word "INK" and of its representatives in modern languages, has caused considerable perplexity among philologists, and has been the cause of many erroneous conjectures. Following are the names by which it is known among those nations who have most employed it:

English	Ink
Low Dutch, Neder Duytsch, Hollandisch	Inkt
German Deutsch	Dinte and Tinte
Old German	Anker, Tinota, Tinta and Dinde
Danish, Norwegian, Norse, Icelandic	Blaek (India Ink, Tusch)
Swedish	Blaeck (India Ink, Tusk)
French	Encre
Old French	Enque
Italian	Inchiostro
Spanish	Tinta
Portuguese	Tinta
Illyrian	Ingvas
Polish	Incaust
Basque	Coransia
Latin	Atramentum
Mediæval Latin	Encaustum
Greek	Melan
Hebrew	D'yo
Chaldee	N'kaso
Arabic	Nikson, Anghas
Persian	Nikson, Anghas
Hindustani, and Hindui	S'yaho, Rosh'na, Kali, shira, mas, murakkat, kalik, midad
Sanscrit	Kali (Black)
Armenian	Syuaghin

The Invention of Lithography

Having been written in 1817 by Alois Senefelder, the inventor and developer of Lithography. *The Invention of Lithography* is, of course, the most practical book ever published on the art of printing from stone. Published in London in 1819, this book was translated into English from the original German by J. W. Muller, well-known American author, in 1911, and during the same year was published by a New York firm.

In translating this book, Mr. Muller has endeavored to have the English edition faithfully represent Senefelder's original German. Even the original technical terms invented by Senefelder have been translated literally.

This book is in two sections. Section I gives a complete history of Stone-Printing from 1796 to 1817 and an interesting account of the circumstances that eventually led to this wonderful invention, including Senefelder's personal experiences and experiments and the development of his invention to a higher state of perfection. Section II is arranged in the form of a practical text-book on the art of printing from stone. The principles and peculiarities of stone-printing and of chemical-printing in general are fully explained. Technical information is in turn presented covering all the processes, tools and materials relating to lithography. The practical information includes many formulas, such as chemical ink, hard borax ink, fluid ink, transfer ink, hard etching ground, soft etching ground, acid-proof ink and crayon.

The Preparation of Printing Ink

The Preparation of Printing Ink, Both Black and Coloured, by William Savage of London, is a commendable work published for the author in London by Longman, Rees, Orme, Brown, Green and Longman, in 1832. The printer was Samuel Bentley, then located at Dorset Street and Fleet Street.

The book, consisting of 186 pages (including general index), is undoubtedly the first complete technical volume published on the manufacture of black and colored printing inks. True, books on printing ink had appeared prior to this, but none so practical or complete.

In Chapter I, headed "Introductory Observations on Printing Ink," the author states that the information adduced is the result of twenty-three years of application to this particular subject, and remarks that "Printing Ink of a rich and durable tone, and of a superior quality, is so essential to the appearance of an elegant book, that it is impossible for any Printer to produce a splendid book, even with all the skill and improved knowledge of the present time, except he be provided with such an article."

In Chapter II, "On the Preparation of Printing Ink by Different Authors Already Published, with Observations on the Properties of Each," Savage refers to "The Dutch Method of making Printing Ink, as given by Moxon in his *Mechanick Exercises, Edit, 1683.*" One of the features of this chapter is that it contains excerpts from Breton, Lewis, Papillon and other earlier authors.

Chapter III, "On the Materials and Implements for Making Ink, With Observations," consists of the author's own practical information on the subject. This information covers Linseed Oil, Rosin, Soap, Lampblack, Ivory Black, Prussian Blue, Indigo, Indian Red, Balsam of Capivi (or Copaiba), Canada Balsam and Implements.

Chapter IV, "On the Preparation of Black Printing

Ink of Different Qualities," a competent treatment of the subject, gives several formulas for black ink.

Chapter V is "On Coloured Printing Inks." This is perhaps the most interesting section of the book for the reason that very little practical information had previously been written on the manufacture of colored inks.

Chapter VI is "On Printing Inks that Change Colour on the Application of an Acid."

The History of Ink

About the year 1860 Thaddeus Davids & Company, 127 William Street, New York City, compiled the matter for a small book entitled *The History of Ink, including its Etymology, Chemistry and Bibliography.* It is a volume of 124 pages including plates and has many unique features. The entire section of 72 pages of text is printed in italics. The printing was done by Francis Hart & Company of New York, and the lithographed title page in colors and gold was by Snyder, Black & Sturn of New York.

Although this book is devoted particularly to the history of writing ink, the text also contains notes on the history of printing and printing ink. The chapter titles are as follows: The History of Ink. Definition. Etymology. Chemistry or Composition of Ink. Bibliography. Writing Inks. Writing Instruments. Importance of Good Ink. Conclusion.

The large number of plates in this volume are all exceedingly interesting. For example, Plate No. 1 is a facsimile of the oldest Hieratic writing known at the time this book was published. A total of 66 examples of writing are reproduced in the plates. There is also a colored plate showing the picture writing of the ancient Mexicans.

Another interesting section illustrates the word "Ink" as spelled and written in different languages.

Ink Manufacture

Ink Manufacture, by Sigmund Lehner, is a well-known technical book, having been translated into English from the German of the fifth edition by Arthur Morris and Herbert Robson. This is the second and enlarged English edition and was published in 1914 by Scott, Greenwood & Son, London, England.

Although this book contains a large number of formulas and recipes for making various kinds of ink (including writing, copying, lithographic, marking and stamping inks), everything is stated so clearly that the ordinary non-technical reader can easily comprehend. The author explains that in preparing the matter for the last edition he has followed the practice of including only such novelties as have proved useful in his own experience. The properties of all raw materials entering into the composition of the recipes are accurately described, which serves the reader as a guide in the purchase of raw materials.

Among the valuable additions to the new edition of this work are several recipes for making inks for typewriter ribbons.

In the make-up of the book, one chapter is devoted to each of the following subjects: Introduction. Varieties of Ink. Writing Inks. Raw Materials of Tannin Inks. The Chemical Constitution of Tannin Inks. Recipes for Tannin Inks. Logwood Inks. Copying Inks. Hektograph Inks. Safety Inks. Ink Extracts and Powders. Preserving Inks. Changes in Ink and the Restoration of Faded Writing. Colored Inks. Red Inks. Blue Inks.

Violet Inks. Yellow Inks. Green Inks. Metallic Inks. Indian Ink. Lithographic Inks and Pencils. Ink Pencils. Marking Inks. Ink Specialties. Sympathetic Inks. Stamping Inks. Laundry or Washing Blue.

Forty Centuries of Ink

Forty Centuries of Ink, or a Chronological Narrative Concerning Ink and Its Backgrounds, by David N. Carvalho, is undoubtedly the largest and most important history of ink produced to the present time. The first edition of this excellent volume, containing 347 pages and general index, was published in 1904 by The Banks Law Publishing Company of New York City.

This history relates principally to writing inks, although certain chapters have been devoted to printing inks, paper, backgrounds for "safety" paper and allied subjects. There are thirty-two extensive chapters, entitled as follows:

I. Genesis of Ink. II. Antiquity of Ink. III. Classical Ink and Its Exodus. IV. Classical Ink and Its Exodus (continued). V. Revival of Ink. VI. Ink of the West. VII. Early Mediæval Ink. VIII. Mediæval Ink. IX. End of Mediæval Ink. X. Renaissance Ink. XI. Ancient Ink Treatises. XII. Study of Ink. XIII. Study of Ink. XIV. Classification of Ink. XV. Official and Legal Ink. XVI. Enduring Ink. XVII. Ink Phenomena. XVIII. Ink Chemistry. XIX. Fraudulent Ink Backgrounds. XX. Fugitive Ink. XXI. Ancient and Modern Ink Receipts. XXII. Ink Industry. XXIII. Chemico-Legal Ink. XXIV. Chemico-Legal Ink (continued). XXV. Ink Utensils of Antiquity. XXVI. Ink Utensils (Quill pen *v.* Steel Pen). XXVII. Substitutes for Ink Utensils ("Lead" and other Pencils). XXVIII.

Ancient Ink Backgrounds (The Origin of Papyrus). XXIX. Ancient Ink Backgrounds (Parchment and Vellum). XXX. Modern Ink Backgrounds (True paper). XXXI. Modern Ink Backgrounds (Wood paper and "Safety" paper). XXXII. Curiosa (Ink and other Writing Materials).

Oil Colours and Printers' Inks

Among the more important and better known books on printing ink subjects is one entitled *Oil Colours and Printers' Inks,* by Louis Edgar Andés. It is a practical technical volume treating of Linseed Oil, Boiled Oil, Paints, Artists' Colors, Lampblack and Printers' Inks—Black and Colored. Translated from the German into English by H. B. Stocks, the first English edition was published at London, by Scott, Greenwood & Son, in the year 1903. The second English edition, revised and enlarged, was produced by the same publishers in 1918. The new edition contains 57 illustrations, the pictures representing devices and apparatus used in the manufacture of varnish, oils, lampblack, paints, printing ink, etc.

Dr. Andés, who is the author of several other technical books, was for a number of years engaged in the manufacture of varnishes, pigments and printing inks, and therefore qualified to write on these subjects. The second English edition of this volume contains a complete description of the purifications, bleaching and boiling of linseed oil; the preparation of lampblack and other colors; the making of pigments, paints and printing inks; and, chapters on poppyseed oil, paint mixing and grinding machinery, the theory of oil boiling, luminous paint and so forth.

Many recipes and formulas for the preparation of paints and printers' inks are given and all technical facts are presented in a clear style. The various chapters are:

I. Linseed Oil. II. Poppy Oil and Walnut Oil. III. Mechanical Purification of Linseed Oil. IV. Chemical Purification of Linseed Oil. V. Bleaching Linseed Oil. VI. Oxidizing Agents for Boiling Linseed Oil. VII. Theory of Oil Boiling and Drying. VIII. Manufacture of Boiled Oil. IX. Adulterations of Boiled Oil. X. Chinese Drying Oil and Other Specialties. XI. Pigments for House and Artistic Painting and Inks. XII. Pigments for Printers' Black Inks. XIII. Substitutes for Lampblack. XIV. Machinery for Color Grinding and Rubbing. XV. Machines for Mixing Pigments with the Vehicle. XVI. Paint Mills. XVII. Manufacture of Ordinary Oil Paints. XVIII. Examination of Pigments and Paints. XIX. Ship Paints. XX. Luminous Paint. XXI. Artists' Colors. XXII. Printers' Inks; Vehicles. XXIII. Printers' Inks: Pigments and Manufacture.

The recipes for printing inks include inks for rotary presses, inks for rapid process, newspaper inks, book inks and illustration inks.

The Chemistry and Technology of Printing Inks

A most instructive book on the chemistry and manufacture of printing inks is that entitled *The Chemistry and Technology of Printing Inks,* published in 1915 by D. Van Nostrand Company, New York City. It was written by Norman Underwood, Chief of the Ink-making Division, Bureau of Engraving and Printing, United States Treasury Department, and by Thomas V. Sullivan, Assistant Chief of the same Division.

The introduction is in itself a practical article and includes the analysis of black engraving and typographic inks, as well as an explanation of the technical terms used throughout the book, such as: Hue, Tint, Shade, Top Hue and Under Hue, Color Strength, Abrasive Quality, Fineness, Oil Absorption, Livering, Shortness, Flow and Length, Tack and Softness, Body Color, Transparency, Opacity, Body, Incompatibility, Bleeding, Fastness to Light, and Atmospheric Influences.

The work has been divided into three main parts:

Part One, "Methods of Testing Raw Materials," has been subdivided into three sections. Section One gives details of laboratory apparatus and incorporates a number of illustrations, *i.e.*, muller and slab, method of rubbing out colors, laboratory mixer, ultra-violet light and case for testing the effect of light on colors, and the viscosimeter for testing heavy bodied oils and varnishes. Section Two concerns the method of analysis. Section Three describes the physical tests of pigments.

Part Two, on "The Manufacture and Properties of Pigments and Varnishes," has been arranged in two sections. Section One deals with dry colors, presents numerous formulas and charts, including "Properties of Vermilion," "Properties of Blues," "Properties of the Chrome Yellows," etc. Section Two offers valuable information concerning oils used in the manufacture of printing inks, such as linseed oil, linseed plate oils, soya bean oil, rosin oil, etc. An interesting feature of this section is an illustration showing the apparatus employed for making printing ink varnishes. The order in which the subjects of Part Two are covered is as follows: Reds, Blues, Yellows, Greens, Oranges, Russets, Citrines, Blacks, Dilutents, Bases, Organic Lake, Oils, Typographic Varnishes, Reducers and Driers.

Part Three, "The Manufacture of Inks," has also been arranged in two sections. In Section One practical data is submitted on the manufacture of inks used for plate and typographic printing. There is also an explanation of terms used in the printing trade as applying to certain conditions arising in the course of work, such as "striking through," "offsetting," "picking up," etc. The halftone illustrations show a mixer for large batches of ink, also a pony mixer. Section two of this chapter deals with the usual difficulties encountered in the use of typographic inks and offers practical solutions.

Modern Printing Inks

Modern Printing Inks, by Alfred Seymour, a practical handbook for printers and printing-ink manufacturers, was published in London by Scott, Greenwood & Son in 1910. Mr. Seymour is a recognized authority on printing subjects and the author of several other books, among which are his *Practical Lithography, Engraving for Illustration* and *Tinplate Printing.*

The utility of this volume to manufacturers of printing ink is assured by the fact that it was written by someone with thorough, practical knowledge of his subject. The book was also designed to help the working printer become better acquainted with the inks he is using every day. Mr. Seymour explains that his main thought was to discuss the manufacture of printing inks in work-a-day fashion, giving, wherever possible, cause and effect as experienced by the printer. This point is well taken, for unless the printing-ink manufacturer is fully aware of the printers' problems and is in a position to supply the exact needs, he will not be offering adequate service.

The various chapters are, consecutively: Introduction. Linseed Oil. Varnish. Dry Colors. Dry Colors—Blacks, Whites, Yellows. Dry Colors—Reds, Browns, Blues, Greens. Lakes. The Grinding of Printing Inks. Ink and Color Mixing. The Characteristics of Some Printing Processes. Driers. Bronze Powders and Bronzing. "Things Worth Knowing."

Coal Tar Dyes and Intermediates

Students of chemistry will find this work by E. de Barry Barnett one of exceptional scientific lucidity. Edited by Samuel Rideal, Fellow of University College, London, and published in London by Balliere, Tindall & Cox, in 1919, this book is one of a series giving a comprehensive survey of chemical industries. It describes the more important synthetic dyes and intermediate compounds from which they are derived. The author explains that he has made no attempt to enumerate all intermediate compounds and dyestuffs actually manufactured or to name the multifarious devices and manufacturing processes proposed, but has confined himself, as far as possible, to those most likely to prove of technical value.

The book is in two parts: Intermediate Compounds, covered by Part I; and Dyestuffs, Part II. These headings are subdivided as follows:

Part I—Section I, Nitration; Section II, Amidation; Section III, Sulphonation; Section IV, Hydroxylation; Section V, Miscellaneous Intermediates.

Part II—Section I, The Nitroso-Dyes; Section II, The Nitro-Dyes; Section III, The Azo-Dyes; Section IV, The Diphenylmethane Dyes; Section V, The Triphenylmethane Dyes; Section VI, The Indamines and Indophenols; Section VII, The Azines; Section VIII, The Oxazines; Section IX, The Thiazines; Section X, The Indigoid Dyestuffs; Section XI, The Anthraquinone Dyes; Section XII, The Quinoline Dyes; Section XIII, The Acridine Dyes; Section XIV, The Sulphur or Sulphide Dyes.

Offset Lithography

The art of printing in the lithographic manner from metal plates on rubber blanket offset presses is fully explained in *Offset Lithography,* by Warren C. Browne. This book was published in 1917 by the National Lithographer Publishing Company, New York City. Incorporated with the main treatise is a supplement on "Photo-Lithography"; also a special section on "Tin Plate Decorating."

This volume should be of value to students and helpful to all employed in the lithographic trade.

The chapters on Offset Lithography are headed and grouped as follows: The Offset Process, The Offset Press, Preparing the Plates, Engraving on Metal Plates, Transferring on Metal Plates, Re-transferring, Retransferring from Type, Proving, Alterations, Preserving the Plates and Offset Press Work. In these chapters the author tells, step by step, how the best offset work may be produced under the most favorable conditions. All technical facts are given in plain English so that even an apprentice may understand.

One large chapter is devoted to Photo-Lithography, which includes a number of formulas used in this process.

The chapters on Tin Plate Decorating are headed:

Tin Plate Decorating, Register Methods, The Presses and Rubber Blankets. A prover's color and sequence chart is a feature of the leading article. Farther on is another chart showing the results of prolonged tests of colors under heat (stoving). This series of articles on tin decorating covers the most improved methods of lithographing on sheet metal by the offset process, and the facts about fine color work are especially interesting.

An appendix entitled, "Useful Information, Solutions, Formulas, Etc.," relates to etching solutions, cleaning preparations, washing-out fluids, *offset inks, litho drawing ink* and miscellaneous advice on the use of inks.

Inks—Their Composition and Manufacture

An instructive book dealing principally with writing fluids is that entitled *Inks—Their Composition and Manufacture,* by C. Ainsworth Mitchell and T. C. Hepworth, published in London by Charles Griffin & Company, Ltd. A second edition of this volume, thoroughly revised and reset, appeared in 1916. A third edition, again revised, enlarged and reset, was produced by the same publishers in 1924, the revisions having been made by C. Ainsworth Mitchell. This edition contains sixty-nine illustrations, including four plates.

Among the interesting features of this book is the "Historical Introduction," which gives a brief history of ink from the days of ancient Egypt to modern times.

The three sections of this work are arranged as follows: Section I, Writing Inks. Chapter I, Carbon and Carbonaceous Inks; Chapter II, Tannin Materials for Inks; Chapter III, Nature of Inks; Chapter IV, Manufacture of Iron Gall Inks; Chapter V, Logwood, Vanadium and Aniline Black Inks; Chapter VI, Colored Writing Inks; Chapter VII, Examination of Writing Inks.

Section II, Printing Inks. Chapter VIII, Early Methods of Manufacture; Chapter IX, Manufacture of Varnish; Chapter X, Preparation and Incorporation of the Pigment; Chapter XI, Colored Printing Inks.

Section III, Inks for Miscellaneous Purposes. Chapter XII, Copying Inks; Chapter XIII, Marking Inks; Chapter XIV, Safety Inks and Papers; Chapter XV, Sympathetic Inks; Chapter XVI, Inks for Miscellaneous Purposes.

This book contains a number of formulas and charts relating to the composition and manufacture of inks; also, there is a bibliography and a list of English patents on writing and copying inks, marking inks, printing inks and inks for miscellaneous uses.

Manufacture of Lake Pigments from Artificial Colours

The *Manufacture of Lake Pigments from Artificial Colours,* by Francis H. Jennison, is an intelligent technical treatise. The first edition was published in 1900 by Scott, Greenwood & Son, London. The second revised edition, produced in 1920 by the same publishers, contains, among other special features, nine color plates on the manufacture of lake pigments.

In revising the matter for the second edition, the author explains that there has been no deviation from the object of dealing with the chemical and physical problems arising in the production of lake pigments, so as to aid the lake-maker in devising his own methods and formulas, and avoiding, as far as possible, definite recipes which may be good under one set of conditions but of no use in others. However, the book includes a large number of practical examples which may be useful in the laboratory.

The general contents of this work are as follows: I. Introduction. II. The Classification of Artificial Colouring Matters. III. The Nature and Manipulation of Artificial Colours. IV. Lake-forming Bodies for Acid Colours. V. Lake-forming Bodies for Basic Colours. VI. Lake Bases. VII. The Principles of Lake Formation. VIII. Red Lakes. IX. Orange, Yellow, Green, Blue, Violet, and Black Lakes. X. The Production of Insoluble Azo Colours in the Form of Pigments. XI. The General Properties of Lakes Produced from Artificial Colours. XII. Striking, Washing, Filtering, and Finishing. XIII. The Matching and Testing of Lake Pigments. XIV. Sketch of Organic Combinations.

In his Introduction Mr. Jennison says in part: "Prior to the introduction of the coal-tar dyes, lakes were made from the natural dyestuffs—cochineal, sapan wood, logwood, Lima wood, fustic, flavin, weld, etc. Many of these lakes are still in the market, and are known by such names as crimson lake, berry yellow, madder lake, Dutch pink, rose lake, leather lake, etc.; but of recent years, except for some few and particular purposes, they have been superseded by lakes made from artificial colours, because the latter can be produced more easily and cheaply, and possess greater staining power, brilliancy and constancy of shade."

The Manufacture of Earth Colours

Having been originally written by the present author's father, Dr. Josef Bersch, the new edition of *The Manufacture of Earth Colours* has been revised and enlarged by Prof. Wilhelm Bersch. It was translated from the third German edition into English by Charles Salter and published by Scott, Greenwood & Son, London, in 1921. The revised edition contains thirty-one illustrations of machines and special appliances used in the preparation of the earth colors. Also, there are charts, analyses and formulas.

Quoting from Professor Bersch's Introductory, "The number of earth pigments is very large, and comprises representatives of all the principal colours. For painting purposes, few pigments beyond the earth colours were known to the ancients; and most of the colours in the paintings which have come down to us from antiquity are pure earth pigments, thus affording proof of their great durability, having retained their freshness unimpaired for hundreds—and some for thousands—of years."

The subjects embraced in this book have been grouped as follows: I. Introductory. II. The Raw Materials for Earth Colours. III. The Preparation of the Colour Earths. IV. White Earth Colours. V. Yellow Earth Colours. VI. Red Earth Colours. VII. Brown Earth Colours. VIII. Green Earth Colours. IX. Blue Earth Colours. X. Black Earth Colours. XI. The Commercial Nomenclature of the Earth Colours.

Printing Inks—Their History, Composition and Manufacture

Francis L. Burt is the author of a brochure entitled *Printing Inks—Their History, Composition and Manufacture,* originally published as a series of articles in *The Inland Printer,* Chicago, during the year 1919-1920.

Mr. Burt presents his information on oils and varnishes used in the manufacture of printing inks, natural and artificial mineral pigments, coal-tar dyes, etc., in a clear and concise manner. Other subjects briefly outlined in this work are: rosin in news inks, the making of lamp-black and glass black, the iron blues, factors in colored inks, chrome yellow, chrome green, ultramarine blue, driers for printing inks, new linseed oil processes, varnish burning, inks for different press speeds, job inks, problems of inks and papers, inks for book printing and Bureau of Standards tests.

APPENDIX A

A ROMANCE OF PRINTING INK

LEVI ADDISON AULT and Frank Bestow Wiborg were close friends as young men living in Cincinnati, Ohio, in 1878. They started together in the printing-ink business in July of that year. Mr. Ault was then about 25 years of age and the junior partner was two and one-half years younger. Both had had the usual public high school education though neither had enjoyed the advantages of a college course training. Both, however, had taken elementary chemistry in school and later studied privately, but as a matter of fact they received their actual knowledge from that good though often hard master, experience. Both had previously tried two or three different kinds of employment with the intention of following some agreeable occupation as regular business men.

In the year mentioned above, Mr. Ault was connected with a Cincinnati concern manufacturing lampblack, rosin oil and kindred products, while Mr. Wiborg was temporarily employed as a salesman, which position he was about to leave to go elsewhere when a business proposal was made by Mr. Ault. This suggestion was that they form a partnership in the manufacture of printing ink. They were influenced in the beginning by Mr. Ault's employer, the lampblack and rosin oil manufacturer referred to, who naturally wanted an additional outlet for the sale of his product. In this project they had little or no encouragement from any other source.

Eventually they put together what money they had and also what capital they could borrow from friends, all of which amounted to a few thousand dollars at the most. They went into this venture not really knowing what the outcome would be nor at the time recognizing the great obstacles in their path. Had they actually known beforehand the difficulties besetting their enterprise, they certainly would have hesitated, and with more time for reflection might have abandoned the undertaking at the start. Youth and courage, as usual, overcame all doubt and both of them being strong and active, they determined to make a success of it even though they had only an uncertain chance. There was no end to the hard work, constant effort and unrelenting perseverance which they gave to organizing and expanding the small enterprise. For many years they strove toward their goal, the establishment of a substantial business. Finally they gained the very desirable reputation of producing the equal, if not the best printing inks, particularly in colors, made in the United States.

This short statement of the modest but ambitious beginning and the laborious development of the Ault & Wiborg firm only faintly tells the story. After more than 47 years of existence, it may be well said that it continues an ever successful business establishment, keeping fully abreast of the continually increasing ink demands of the printing industry.

The undaunted courage and enterprise required in the commercial exploits of these two young Americans were characteristic of the country of their birth. True to the spirit of their well-chosen motto, "Hic et Ubique," their corporation has extended its operations to the great industrial centers of the most remote countries of the world, establishing there its plants and agencies. In the United States there is hardly a city of marked importance that does not attest the vision of these two enterprising originators of the business by the establishments of their company. Looking well into the future, one may see the continued growth of a corporation whose fundamentals are so soundly laid that perpetuity is assured.

It was but natural that one or both of these life-long partners, whose travels over the world had given them special facilities and opportunities for studying the history of their business, should desire to write a record of it. Not as a memorial to their own enterprise, but as a work that might be useful to all who are interested in this great essential connected with the activities of man applied to the printing industry. It fell to Frank B. Wiborg to undertake this work, which, as originally planned by him, would appear on the occasion of the fiftieth anniversary of the foundation of the company, July, 1928. Circumstances altered that intention, making it desirable that this history appear in 1926. It is quite probable that the rapid changes that are taking place in this business will necessitate a later edition on the arrival of the semi-centennial commemoration. In that event, a record or description of the several new processes in prospect almost revolutionary should be incorporated. Perhaps these developments, in which the Ault & Wiborg establishment is taking a prominent part, may be published then to the satisfaction of ink manufacturers, publishers and printing lovers everywhere.

With a background of nearly half a century, this corporation envisages the future with much optimism, believing that the refinements and general improvements that are being made in printing not only surpass all previous rates of progress, but will considerably enhance the welfare of the world in both an artistic and a material sense. Indeed optimism has proved a valuable asset in the remarkable development of this world-wide business.

This history of *Printing Ink* should stand out among the many writings and treatises on the same subject that have been written during the past sixty years. It should serve to increase the prestige so successfully won and so gracefully maintained by these pioneers of the printing ink industry.

APPENDIX B

MODERN SCHOOLS FOR PRINTING AND KINDRED TRADES

TECHNICAL schools in different parts of the United States, in England and other parts of Europe, offer today the most liberal terms and encouragement to ambitious young men and women desirous of becoming educated and trained in every branch of the printing industry.

Mr. John Clyde Oswald of New York City, in an essay entitled "Education in the Printing Trade," recently said that there are in the United States at this time more than twenty-five hundred schools, including those in the public school system, in which students are trained in setting type and running presses.

Such progressive vocational schools, supported mainly by printers actually engaged in business, assisted by the allied trade and supply houses, both manufacturers and dealers, and in one important instance abroad supported by a municipality—the London County Council—all afford and offer to everyone free, or practically so, their remarkable facilities.

To enumerate all would take up much space, but of the more prominent ones, some of them internationally known, a few should be specially mentioned.

Under the auspices of the International Printing Pressmen and Assistants' Union of North America was established several years ago a technical training school at

Pressmen's Home, Tennessee, a small town about sixty miles from Nashville. It has excellent equipment, under able men, skilled and experienced in different branches of the profession. It graduates every year about two hundred young men well qualified to go out and earn their way in the world. This organization has also inaugurated a scheme of apprentice pressmen's correspondence courses, which has proven efficient and satisfactory. To those unable to leave home to attend a regular technical school, instruction in this way is the next best thing. Another feature of the organization is an Engineering Department, through which personal service is given employing printers and newspaper publishers free of cost.

The Pressmen's Home is now contemplating the operation of zone schools at Cleveland, Chicago, San Francisco, Montreal and other cities as soon as possible, to be conducted jointly by the headquarters organization at Pressmen's Home, together with the permanent local printing organizations in different cities. A branch school of this type has been satisfactorily operated at Des Moines, Iowa, for three years past.

Another important printing trade educational school is the Ohio Mechanics Institute at Cincinnati. This was started several years ago and is prospering in a high degree. They have two-year full-time educational courses, with special instruction in printing and lithography in various branches, and all the instruction necessary is provided to make scholars proficient with reasonable application.

An important school at Indianapolis is conducted by the United Typothetæ of America; another successful one at Pittsburgh, by the Carnegie Institute of Technology.

Very prominent for the immediate future is the Lithographic Technical Foundation, Inc., under the able direction of Dean Schneider of the Cincinnati (Ohio) University, under whose auspices this great movement was inaugurated, supported by the lithographers and supply-houses in different parts of the United States. A large sum of money, $750,000, has already been raised, and the amount will doubtless be increased to a million. This has been done entirely by voluntary subscription with the idea of making it the most useful and broad-minded, liberal undertaking of its kind in connection with lithography that has ever been undertaken. The plan is to improve the general character of the industry, as well as the education of those engaged in that branch of printing.

Two schools in New York, one for composing room apprentices, and the other for pressroom apprentices, are conducted by the unions and employers acting individually. A noteworthy enterprise, with a promising future, is the Newspaper Printing Press Apprentices Trade School, opened December 1st, 1925, and operated jointly by the New York Printing Pressmen's Union No. 2 and The Publishers' Association, under the auspices of the New York City Board of Education.

Perhaps the largest and most successful school of the kind outside the United States is the London School of Printing and Kindred Trades, under the direction of Mr. J. R. Riddell. This institution, now in its fifth year, has an average attendance during the school year of over 3,000 and rapidly growing.

The Paris Municipal Printing School (Ecole Estienne), founded in 1873, is a fine example of the many French technical trade schools. Great universities teaching all branches of modern printing now flourish in Vienna (Austria), Leipsic (Germany), Milan (Italy), Birmingham and Manchester (England). In fact, technical schools exist everywhere in Enrope.

Educational work along these lines is bound to prove useful and an uplift to the followers of a great industry by influencing beginners to get the proper start. There has never been a time in all history when the opportunity to become trained and educated in all branches of the printing industry was so advantageous as at the present time.

Could we with ink the ocean fill,
And were the heavens of parchment made,
Were every stalk on earth a quill,
And every man a scribe by trade;
To write the love of God above,
Would drain the ocean dry;
Nor could the scroll contain the whole,
Though stretch'd from sky to sky.

—Trans. from "Chaldee Ode."

INDEX

INDEX

INDEX

INDEX